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EPONYMS.

BY SIR D'ARCY POWER, K.B.E., LONDON.

VI. SIR JAMES PAGET (*continued*).

SIR JAMES PAGET read a paper "On a Form of Chronic Inflammation of Bones (Osteitis Deformans)" on November 14, 1876. It is published in the sixtieth volume of the *Medico-Chirurgical Transactions* and immediately attracted a large amount of attention. Packard, Steele, Kirkbride, and Elting wrote upon it in the United States; Lannelongue, Marie, Pozzi, Richard, Thiebierge, and Joncheray in France; Gaugele and Wollenberg in Germany. But to this day little has been added to Paget's description, and the cause and curative treatment are still unknown.

The paper begins: "I hope it will be agreeable to the Society if I make known some of the results of a study of a rare disease of bones.

"The patient (*Fig.* 128) on whom I was able to study it was a gentleman of good family, whose parents and grandparents lived to old age with apparently sound health, and among whose relatives no disease was known to have prevailed. Especially, gout and rheumatism, I was told, were not known among them; but one of his sisters died with chronic cancer of the breast.

"Till 1854, when he was forty-six years old, the patient had no sign of disease, either general or local. He was a tall, thin, well-formed man; father of healthy children; very active in both body and mind. He lived very temperately, could digest, as he said, anything, and slept always soundly.

"At forty-six, from no assigned cause, unless it were that he lived in a rather cold and damp place in the North of England, he began to be subject to aching pains in his thighs and legs. They were felt chiefly after active exercise, but were never severe; yet the limbs became less agile or, as he called them, 'less serviceable', and after about a year he noticed that his left shin was misshapen. His general health was, however, quite unaffected.

"I first saw this gentleman in 1856, when these things had been observed for about two years. Except that he was very grey and looked rather old for his age, he might have been considered as in perfect health. He walked with full strength and power, but somewhat stiffly. His left tibia (*Fig.* 126), especially in its lower half, was broad, and felt nodular and uneven, as if not only itself, but its periosteum and the integuments over it were thickened. In a much less degree similar changes could be felt in the lower half of the left femur. This limb was occasionally, but never severely, painful, and there was no tenderness on pressure. Every function appeared well discharged, except that the urine showed rather frequent deposits of lithates. Regarding the case as one of chronic periostitis, I advised iodide of potassium and liquor potassæ; but they did no good.

"Three years later I saw the patient with Mr. Stanley. He was in the same good general health, but the left tibia had become larger, and had a well-marked anterior curve (*Fig.* 127), as if lengthened while its ends were held in place by their attachments to the unchanged fibula. The left femur also was now distinctly enlarged, and felt tuberous at the junction of its upper and middle thirds, and was arched forwards and outwards so that he could not bring the left knee into contact with the right. There was also some appearance of widening of the left side of the pelvis, the nates on this side being flattened and lowered, and the great trochanter projecting nearly half an inch further from the middle line. The left limb was about a quarter of an inch shorter than the right. The patient believed that the right side of his skull was enlarged, for his hats had become too tight; but the change was not clearly visible. . . . .

FIG. 126.

"In the next seventeen years of his life I rarely saw him, but the story of his disease, of which I often heard, may be briefly told, and with few dates, for its progress was nearly uniform and very slow. The left femur and tibia became larger, heavier, and somewhat more curved. Very slowly those of the right limb followed the same course, till they gained very nearly the same size and shape. The limbs thus became nearly symmetrical in their deformity, the curving of the left being only a little more outward than that of the right. At the same time, or later, the knees became gradually bent, and, as if by rigidity of their fibrous tissues, lost much of their natural range and movement.

"The skull became gradually larger, so that nearly every year, for many years, his hat, and the helmet that he wore as a member of a Yeomanry Corps needed to be enlarged. In 1844 he wore a shako measuring twenty-two and a half inches inside; in 1876 his hat measured twenty-seven and a quarter inches inside. In its enlargement however, the head retained its natural shape and, to the last, looked intellectual, though with some exaggeration.

"The changes of shape and size in both the limbs and the head were arrested, or increased only imperceptibly, in the last three or four years of life.

"The spine very slowly became curved and almost rigid. The whole of the cervical vertebræ and the upper dorsal formed a strong posterior, not angular, curve; and an anterior curve, of similar shape, was formed by the lower dorsal and lumbar vertebræ. The length of the spine thus seemed lessened and from a height of six feet one inch he sank to about five feet nine inches. At the same time the chest became contracted, narrow, flattened laterally, deep from before backwards, and the movements of the ribs and of the spine were lessened. There was no complete rigidity, as if by union of bones, but all the movements were very restrained, as if by shortening and rigidity of the fibrous connections of the vertebræ and ribs.

FIG. 127.

"The shape and habitual posture of the patient were thus made strange and peculiar. His head was advanced and lowered, so that the neck was very short, and the chin, when he held his head at ease, was more than an inch lower than the top of the sternum. The short narrow chest suddenly widened into a much shorter and broad abdomen, and the pelvis was

wide and low. The arms appeared unnaturally long, and, though the shoulders were very high, the hands hung low down by the thighs and in front of them. Altogether, the attitude in standing looked simian, strangely in contrast with the large head and handsome features. . . . .

" But with all these changes in the shape and mobility of the head, spine, and lower limbs, the upper limbs remained perfect, and there was no disturbance of the general health.

" In 1870, when the disease had existed sixteen years, the left knee-joint was, for a time, actively inflamed, and its cavity was distended with fluid. But the inflammation soon subsided, only leaving the joint stiffer and more bent.

" About this time some signs of insufficiency of the mitral valve were observed, but the patient now lived so quietly, and moved with so little speed, that this defect gave him no considerable distress.

" In December, 1872, sight was partially destroyed by retinal hæmorrhage, first in one eye, then in the other, and at nearly the same time he began to be somewhat deaf. In the summer of 1874 he had frequent cramps in the legs, and neuralgic pains, which were described as 'jumping over all the upper part of the body except the head', but change of air seemed to cure them.

" In January, 1876, he began to complain of pain in his left forearm and elbow which, at first, was thought to be neuralgic. But it grew worse, and swelling appeared about the upper third of the radius and increased rapidly, so that, when I saw him in the middle of February, it seemed certain that a firm medullary or osteoid cancerous growth was forming round the radius. . . . After this time . . . . there was gradual failure of strength and emaciation, and on March 24, after two days of distress with pleural effusion on the right side, he died.

" The body was examined five days after death. As it lay on a flat board its posture was remarkable, for the head was upraised to the level of the sternum, being supported by the rigid and arched spine, and the lower limbs, with the knees bent and stiff, rested on the heels and nates.

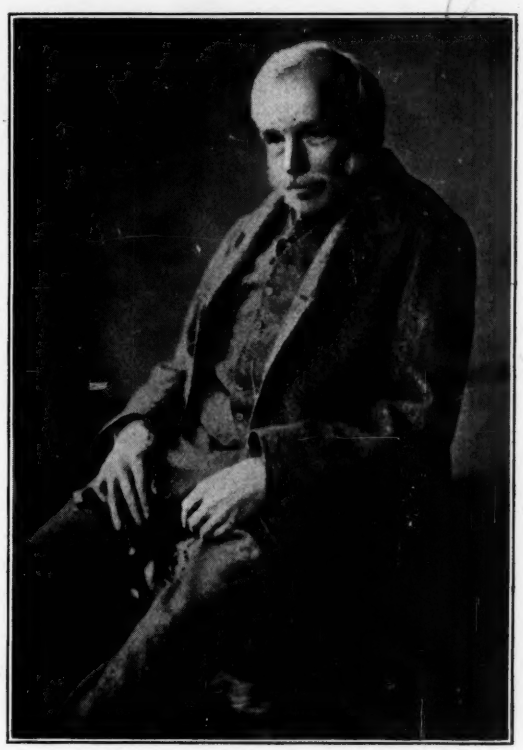

FIG. 128.

Figs. 126, 127, and 128 are from photographs of the patient taken about six months before death, *Figs.* 126 and 127 being copied from *Med.-Chir. Trans.*, vol. lx.

" The pleura covering the right lung contained small nodular masses of pale cancerous substance, and there were many small masses of cancer in the left pleura and in the anterior mediastinum. The upper third of the left radius was involved in a large ovoid mass of pale grey and soft white cancerous substance, similar to that of the nodules in the pleuræ and mediastinum.

" The right femur, the left tibia, the patellæ, and the upper part of the skull were taken for separate examination. In the other bones of the skeleton, except the left radius, no signs of disease appeared externally, but I regret that they were not all more carefully examined, for I think that, at least in the clavicles and pelvis, some changes like those in the long bones of the lower limbs would have been found."

Sir James then considers in considerable detail the pathological changes which the bones had undergone, and arrives at the conclusion that the bones of the vault of the skull were in every part increased to about four times the natural thickness. In the long bones the periosteum was not visibly changed, not thicker, or more than usually adherent. The outer surface of the walls of the bones was irregularly and finely granular, and everything seemed to indicate a greatly increased quantity of blood in the vessels of the bone. The compact substance of the bones was in every part increased in thickness, the thickening being due to outward expansion and some superficial growth. In some places there were faint appearances of separation of parts of the outer layers of the walls, and of these becoming thick and porous, while the corresponding parts of the inner layers were less changed; but in the greater part of the walls the whole construction of the bone was altered into a hard, porous, or finely reticulate substance, like very fine coral. In some places, especially in the walls of the femur, there were small ill-defined patches of pale, dense, and hard bone, looking as solid as brick (*Fig.* 129). Details are then given of four other cases which Sir James had seen or heard of, and which he thought might be similar. The paper concludes with the results of an exhaustive search through the literature and the museum specimens of enlarged bones.

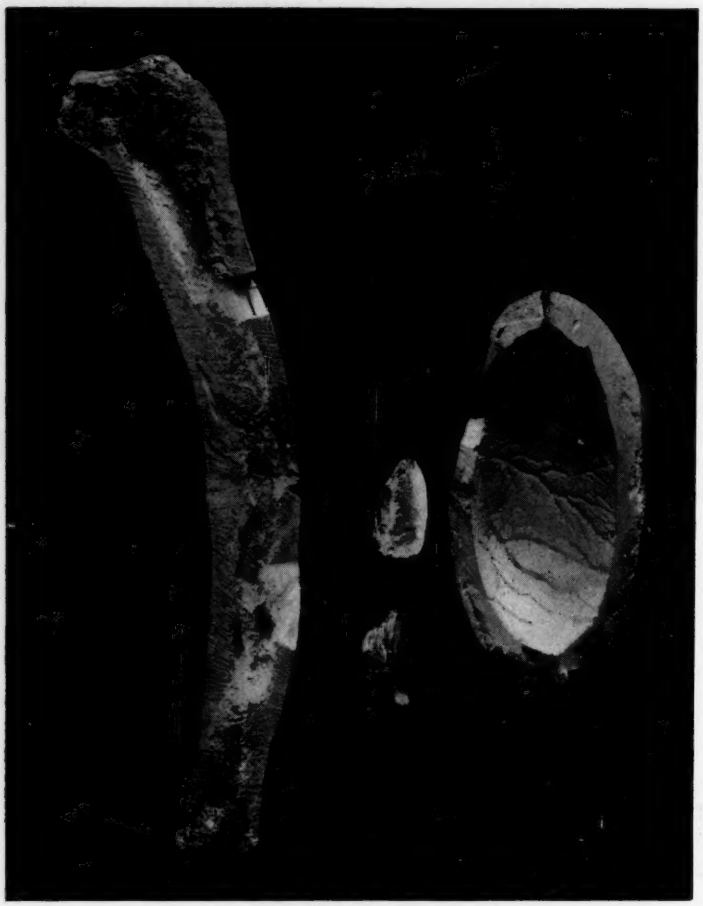

FIG. 129.—Sections of the femur, patellæ, and calvaria from Sir James Paget's case of osteitis deformans. *From St. Bartholomew's Hospital Museum; by kind permission of the Governors.*

He says: "Holding, then, the disease to be an inflammation of bones, I would suggest that, for brief reference, and for the present, it may be called, after its most striking character, Osteitis deformans. A better name may be given when more is known of it." No better name, however, has yet been found for the condition, and when it is not called 'Paget's disease of bone' it is known as 'osteitis deformans'.

Paget's name is also associated with the haustus hydrargyri perchloridi cum potassii iodido of the St. Bartholomew's Hospital Pharmacopœia. It appears for the first time in the edition of 1882, and has always been known as 'Paget's mixture'. The formula is: solution of perchloride of mercury, one fluid drachm; iodide of potassium, five grains; compound tincture of cardamoms, twenty minims; and distilled water to one fluid ounce.

HYDROCEPHALUS.

By JOHN FRASER and NORMAN M. DOTT, Edinburgh.

Hydrocephalus has hitherto ranked as one of the most intractable and unpromising of the diseases of childhood. A multitude of surgical procedures has from time to time been instituted for the relief of the condition, but almost without exception they have failed in their purpose, and the rare occasions on which they have succeeded have left one wondering whether, after all, the success was no more than a coincidence—whether, in fact, improvement would have occurred if nothing active had been done, for spontaneous arrest of hydrocephalus is an actual—though rare—possibility. This unsatisfactory state of affairs depended largely upon erroneous ideas regarding the etiological pathology of the disease.

As early as 1862 Hilton,[1] in his Lectures on *Rest and Pain*, described varieties of obstructive hydrocephalus arising from congenital obliteration of the aqueduct of Sylvius, and from occlusion of the foramina present in the roof of the fourth ventricle. The clue which Hilton thus gave to the pathology of certain types of the disease does not appear to have produced in the past any operative interference of lasting and definite value, and we owe to Dandy and his co-workers the establishment of operative principles which hold out the prospect, as far as we can at present tell, of permanent cure of the disease.

In the course of our work we have had the opportunity of treating a number of children and infants, the victims of hydrocephalus, and since the publication of Dandy's[2] original papers we have followed up the subject with the closest interest; after four years partly spent in observing and treating these cases we venture to put forward our experiences and our results.

THE NORMAL ANATOMY AND PHYSIOLOGY OF THE PARTS INVOLVED.

It is essential to have a proper idea of the processes involved in the production and absorption of the cerebrospinal fluid, and of the relationship of the parts connected with its circulation. Such knowledge is fundamental, because the development of hydrocephalus necessarily entails an error either in the production, circulation, or absorption of the fluid.

The Production of the Cerebrospinal Fluid.—

1. *From the Choroid Plexuses.*—We may assume that the bulk of the cerebrospinal fluid is derived from the choroid plexuses which lie in the lateral ventricles. Dandy[3] has produced confirmatory evidence of this assumption by experiments on dogs. He occluded the foramen of Monro by a strip of fascia or peritoneum, and a dilatation of the corresponding lateral ventricle resulted. He occluded the iter by means of an oiled gelatin capsule containing cotton-wool, and a dilatation of the two lateral and the third ventricles ensued. He repeated these experiments, excising in the first case the corresponding choroid plexus, and in the second the choroid plexus of both lateral ventricles. In the first instance the lateral ventricle collapsed completely; in the second, a slight degree of dilatation of the ventricles occurred on account of the remaining choroid plexus of the third ventricle. Absolute proof was thus given that the choroid plexus is the site of production of the cerebrospinal fluid.

The method by which the fluid is actually produced from the villi is uncertain. It is not yet possible to say whether the process is one of secretion, filtration, or dialysation. The fluid differs so widely from that secreted by most other glands, and it so persistently retains its freedom from contamination by such body fluids as bile in jaundice, or by drugs

when they are injected into the body, that we must assume that whatever the method of production, certain strong selective actions are at work. The time in embryonic life at which the formation of the fluid first appears remains doubtful, but one anatomical detail would suggest that it is unlikely it is produced in any quantity before the fifth month of intra-uterine life. It is only after the fifth month that the tela choroidea demonstrates the perforations of the foramina of Magendie and Luschka. Therefore any production in quantity of cerebrospinal fluid before the fifth month would have no obvious means of exit from the ventricular system.

2. *From the Perivascular Spaces.*—Another possible source of the production of the cerebrospinal fluid exists in the perivascular spaces. Lymphatics, as we generally understand them, do not exist in the brain or meninges; their place is taken by perivascular spaces or channels, and these cannot be grouped as lymphatics, because the fluid which they contain has neither the constitution nor the characters of lymph. The perivascular

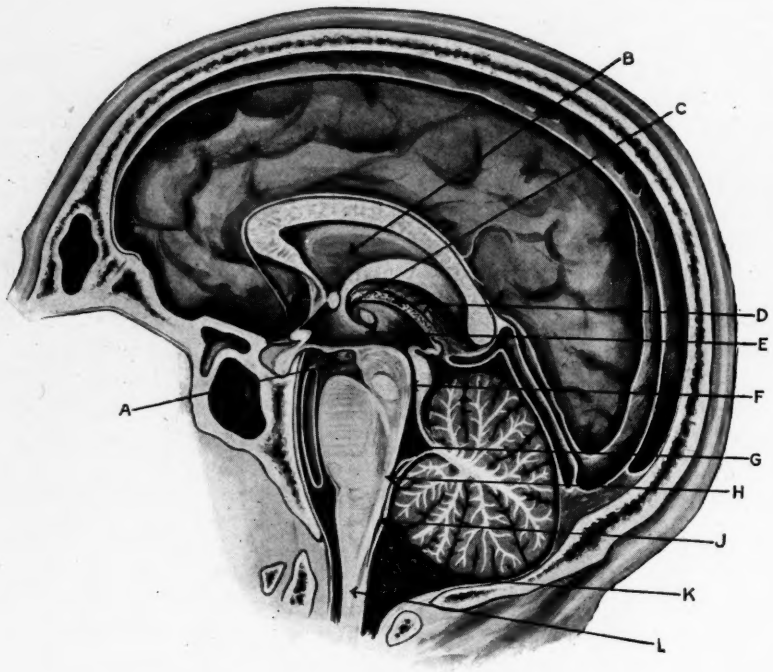

FIG. 130.—Sagittal section through head, showing the anatomy of the ventricular system and basal subarachnoid cisterns. (A) Cisterna interpeduncularis. (B) Septum pellucidum. (C) Foramen of Monro. (D) Choroid plexus of third ventricle. (E) Third ventricle. (F) Aqueduct of Sylvius. (G) Fourth ventricle. (H) Choroid plexus of fourth ventricle. (J) Foramen of Magendie. (K) Cisterna magna. (L) Central canal of spinal cord.

spaces extend throughout the cerebral vascular system, even to the finer capillaries (their presence was fully demonstrated by Spina[4]), and it would seem that they contain fluid of simpler constitution than lymph, which passes into them from the blood-stream.

The perivascular spaces communicate with the subarachnoid space, and therefore the fluid of the former must to some extent be included in the cerebrospinal fluid. It is an interesting point in the physiology of the central nervous system, though not directly applicable to the subject of hydrocephalus, that the waste products of the central nervous system probably accumulate in the fluid of the perivascular spaces, and are thence conveyed into the subarachnoid space to mix with the cerebrospinal fluid.

The Course of the Fluid after Production.—The fluid circulates along the ventricular system and escapes from it through the medium of the central rounded foramen

of Magendie, and the more slit-like lateral foramina of Luschka. It is now in the subarachnoid space, and at first it tends to collect in the large subarachnoid cisterns which lie at the base of the brain (*Fig.* 130), the cisterna magna on the dorsal aspect and the cisterna pontis with its various subdivisions on the ventral aspect. The value of the cisterns is two-fold—they stabilize the pressure of the cerebrospinal fluid, and they render possible a uniform distribution of the fluid in its further progress over the cerebral hemispheres. From the subarachnoid spaces and cisterns the fluid passes in two directions—a small proportion passes downwards through the foramen magnum into the subarachnoid space of the spinal meninges, while the larger proportion escapes upwards between the mid-brain and the tentorium cerebelli to be distributed in the wide area of the subarachnoid space which covers the cerebral hemispheres : it is in this area that absorption of the fluid occurs.

The Method of Absorption of the Fluid.—

1. *Pacchionian Bodies.*—It was formerly held that the Pacchionian bodies were the media through which the cerebrospinal fluid passed from the subarachnoid spaces into the cerebral sinuses (*Fig.* 131). Recently, however, objection has been raised to this view for two reasons—first, because the Pacchionian bodies are demonstrable only in man and in certain anthropoids ; secondly, because in man and anthropoids they are only met with in adult life.

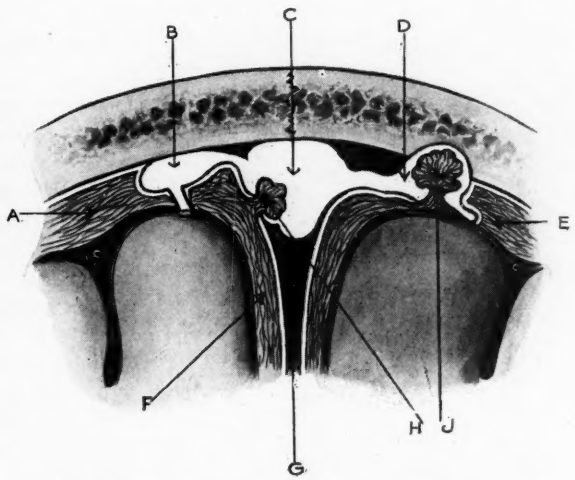

FIG. 131.—Diagrammatic representation of mechanism of absorption of cerebrospinal fluid, showing arachnoid villi connected with subarachnoid space and projecting into a cerebral blood sinus. (A) Subarachnoid space. (B) Lacuna lateralis. (C) Superior longitudinal sinus. (D) Lacuna lateralis. (E) Subarachnoid space. (F) Subarachnoid space. (G) Falx cerebri. (H, J) Arachnoid villi (Pacchionian bodies).

2. *Arachnoid Villi.*—Weed[5] and his collaborators have demonstrated that, while the Pacchionian bodies undoubtedly play a part in absorption of the cerebrospinal fluid, other means exist. Using a Prussian-blue reaction they were able to demonstrate the occurrence of what they have termed 'arachnoid villi'. These are delicate coil-like structures of interlacing strands of connective tissue prolonged from the arachnoid into the walls of the dural sinuses. The Pacchionian bodies are examples of hypertrophied arachnoid villi, and this explanation disposes of the two objections already quoted. There is, therefore, the passage of the cerebrospinal fluid into the blood-stream of the dural sinuses through the medium of the arachnoid villi and, in later life, through hypertrophied examples of these—the Pacchionian bodies. The means by which the cerebrospinal fluid passes from the arachnoid villi into the venous sinuses is a double one—there is a process of filtration from a point of higher to one of lower pressure, and there is a process of osmosis from a fluid of low colloid and crystalline content to one of higher content.

3. *Arachnoid Mesothelial Cells.*—Weed[6] has demonstrated another method by which absorption of the cerebrospinal fluid may occur. Surgeons have recognized that on exposing the outer aspect of the dura (as, for example, in such a procedure as an osteoplastic craniotomy) there is often a faint oozing of cerebrospinal fluid through what appear to be tiny pores in the dural structure : further, the blood in this situation has a distinctive watery appearance. Weed believes he has explained these occurrences by demonstrating small nest-like collections of arachnoid mesothelial cells which lie in the dura and are in continuity with the arachnoid villi. Through such channels there is in all probability a slight escape of cerebrospinal fluid on to the outer surface of the dura, where it is absorbed into the circulation.

4. *Lymphatic Absorption.*—An accessory pathway of absorption exists through the medium of the lymphatic system. Key and Retzius were able to inject the cervical lymphatics from the spinal subarachnoid space, and later observers have obtained similar results. The practical importance of this demonstration was not fully appreciated until Weed, using the Prussian-blue method, showed that a subarachnoid injection reached the perineural lymphatics of the cranial nerves and the cervical vessels and glands. Evidently, then, the subarachnoid space is continuous along the perineural spaces of the cranial nerves with the perineural lymphatic channels, and through the medium of this connection an absorption of cerebrospinal fluid must occur.

The Special Anatomy Involved.—Of the special anatomy of the parts little need be said. A description of many of the anatomical details is unnecessary in a contribution of this description; therefore only those points which have a direct bearing on the problems of hydrocephalus are mentioned.

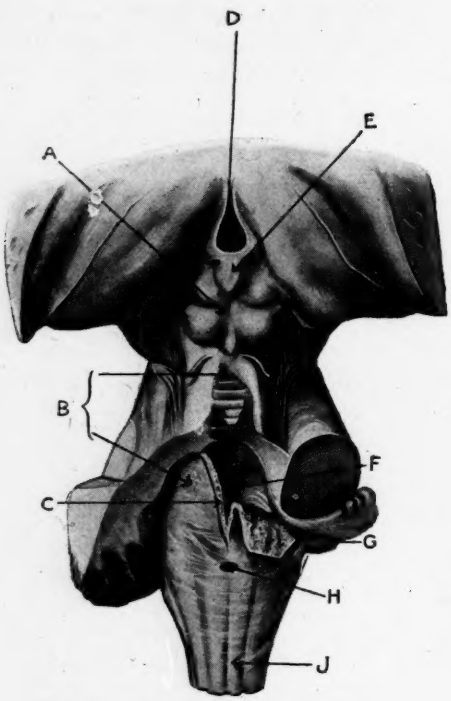

FIG. 132.—Dissection exposing the roof of the fourth ventricle. The lower part of the roof has been partly opened and turned down. (A) Lamina quadrigemina. (B) Roof of fourth ventricle. (C) Choroid plexus of fourth ventricle. (D) Third ventricle. (E) Pineal body. (F) Floor of fourth ventricle. (G) Foramen of Luschka. (H) Foramen of Magendie. (J) Medulla oblongata.

The large proportion of the cerebrospinal fluid is formed within the lateral ventricles in which lies the bulk of the choroid plexus. The fluid passes by the foramina of Monro into the narrow cleft-like space which separates the mesial surfaces of the thalami—the third ventricle. This ventricle contains a choroid plexus, and therefore it is the site of production of a certain amount of cerebrospinal fluid.

The fluid leaves the third ventricle by the Sylvian aqueduct to pass into the fourth ventricle. The lumen of the Sylvian aqueduct is somewhat narrowed at its two extremities—a point of importance we shall allude to later in connection with congenital obstructive hydrocephalus. In regard to the fourth ventricle, there are certain details in the roof of the ventricle which require mention, as they have a close bearing on the subject under discussion. Viewed in median sagittal section (*see Fig.* 130), the roof of the ventricle appears as a tent-like structure, the wings of which, where they come together, bound the space 'the recessus tecti', which penetrates the cerebellar medulla between the superior and inferior vermes. The upper wing of the tent is formed by the 'superior medullary velum' connected with the corpora quadrigemina above, the cerebellar medulla below and the superior cerebellar peduncles laterally.

It is, however, in the lower wing of the tent that, from our point of view, the chief interest lies (*Fig.* 132). It is composed of two parts, an upper thicker crescentic plate of white matter (the inferior medullary velum) and a lower extremely thin membrane (the tela choroidea). The latter structure is formed in a morphological sense of ependyma only, though actually it is supported by a backing of pial tissue. During the early part of fœtal life the tela choroidea is a complete membrane, but about the fifth month it becomes perforated at its lower extremity by an aperture which remains throughout life, the foramen of Magendie. About the same time two additional clefts (the foramina of Luschka) appear at the lateral extremities of the tela, behind the upper roots of the ninth nerve in the pouch-like extension of the ventricle beneath the flocculus, and through these three apertures, and probably through them alone, the system of ventricular cavities and the central canal of the spinal cord are brought into communication with the subarachnoid space.

Three groups of choroid plexus appear in the roof of the fourth ventricle—a medial and two lateral—and therefore a proportion of the cerebrospinal fluid is formed within this space.

Having escaped from the fourth ventricle into the subarachnoid space by the foramina of Magendie and Luschka, the fluid is free to pass forwards over the hemispheres or caudally into the spinal subarachnoid space. We have elsewhere described the absorption of the fluid from the cranial subarachnoid space, and we are therefore now in a position to appreciate the cycle of the fluid from its point of production to the area of its resorption into the blood-stream of the various sinuses.

THE ESSENTIAL ERROR IN THE FORMATION OF A HYDROCEPHALUS.

By the term hydrocephalus we mean an accumulation of cerebrospinal fluid within the cavity of the skull, and, keeping in view the outline which we have given of the formation, circulation, and absorption of the cerebrospinal fluid, we may systematize the possible origins of the disease as follows: (*a*) *It may be due to an excessive production of fluid;* (*b*) *It may be due to an obstruction in some portion of the route along which the fluid circulates;* (*c*) *The production and circulation of the fluid remaining normal, there may be an interference with the absorption of the fluid.*

Based upon these three possibilities, a reasonable and scientific classification of the disease can be made, which will include moreover all varieties of the disease.

VARIETIES OF CLASSIFICATION.

Hitherto different varieties of hydrocephalus were recognized in describing the disease. For example, hydrocephalus was classified as 'acute' or 'chronic', according to the rapidity with which the fluid accumulated, or dependent on its association with coincident acute inflammatory reaction in the meningeal structures. Hydrocephalus was spoken of as 'internal' or 'external', according to whether the fluid accumulated within the ventricular system or in the extracerebral tissue of the arachnoid spaces. Further, the disease was classified as 'congenital' or 'acquired', according to the history of its incidence and occurrence. Such an irregular and rambling classification had no proper basis. The occurrence of an external hydrocephalus as a primary condition distinct from a co-existing internal hydrocephalus has been questioned, and its occurrence is universally accepted as a very rare condition. In our personal experience we have seen two examples of it. Both were cases in which a marked degree of hydrocephalus was present at birth, and in both cases life persisted for only a few hours after birth. In the two instances a similar condition was found (*Fig.* 133); there was a congenital absence of the quadrigeminal plate and the superior cerebellar peduncles.

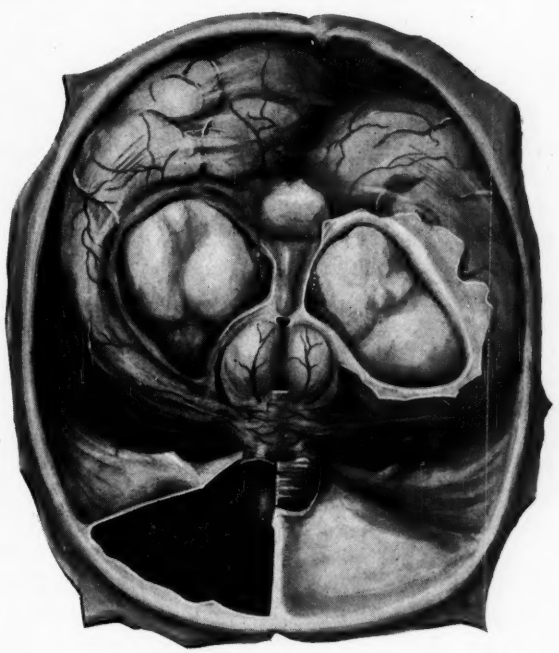

FIG. 133.—Drawing from a specimen of congenital (developmental) hydrocephalus. The brain and skull are grossly deformed. The upper part of the quadrigeminal plate is absent, and the open ends of the Sylvian aqueduct are seen. The cerebral tissue forming the roofs of the lateral ventricles is defective, so that these cavities open on to the dorsal surface of the brain. A ruptured membrane of attenuated cerebral tissue attached to the right defect suggests an extreme ventricular distention at an earlier period. The posterior fossa of the skull is disproportionately small and shallow.

The posterior wall of the Sylvian aqueduct was absent, and the cerebrospinal fluid which was produced within the ventricles was poured directly into the sub-meningeal space. The result was that the cerebral tissues were atrophied and ill-developed, and displaced forwards into the frontal regions of the cranium, the greater portion of the skull being occupied by cerebrospinal fluid. The condition, therefore, approximated as closely as possible to a pure external hydrocephalus ; but, even in this instance, there was to some extent a co-existing, though slight, internal hydrocephalus.

The classification of 'acute' and 'chronic' hydrocephalus was specially unfortunate. Apparently in the minds of many observers acute hydrocephalus was synonymous with the development of a basal meningitis. But, whatever the origin of the condition, all varieties of hydrocephalus are chronic in their formation, though the actual period of time involved may vary within wide limits.

Something is to be said for the method of classification into 'congenital' and 'acquired' varieties of the disease—a considerable proportion of cases can without much difficulty be grouped into one or other of these two classes—but the independent use of the two terms is not sufficiently descriptive of the condition of affairs.

The Classification Suggested by Dandy.—Recognizing the unsatisfactory condition of the classification nomenclature, Dandy[7] has suggested that the following is a scientific and inclusive grouping of the possibilities :—

Hydrocephalus due to	Diminished absorption of cerebrospinal fluid	1. Communicating hydrocephalus (due to adhesions in the subarachnoid space) 2. Obstructive hydrocephalus—Congenital, atresiæ, adhesions, tumours 3. External hydrocephalus ?
	Increased production of cerebrospinal fluid	1. Acute hydrocephalus (increased fluid from inflammatory products in acute meningitis and trauma) 2. Communicating hydrocephalus (due to occlusions of the vena magna Galeni)

This classification is complete in so far as it would appear to include all varieties of hydrocephalus. From the point of view of the pediatric surgeon, however, it includes types of the disease which, if they actually exist as clinical entities, have little or no relationship to surgical treatment. Under this criticism we include external hydrocephalus, acute hydrocephalus, and communicating hydrocephalus due to occlusion of the vein of Galen.

We have stated our experience with external hydrocephalus ; we do not believe that acute hydrocephalus exists as a condition calling for surgical interference ; and, while we realize that a non-obstructive variety of hydrocephalus, said to be due to occlusion of the vein of Galen, has been produced experimentally (Dandy[8]), its clinical existence is exceedingly doubtful, and it certainly can be accepted as negligible in our estimation of hydrocephalus work.

Excluding, therefore, for practical purposes these three varieties, only the congenital anomalies and communicating and obstructive types (Dandy) remain to be considered.

We would further venture to criticize the title of 'communicating hydrocephalus' (as contrasted with 'obstructive hydrocephalus') as being insufficiently expressive of the condition, or even misleading. According to Dandy, the 'communicating' variety depends upon pia-arachnoid adhesions. The normal filmy pia-arachnoid tissue is replaced by a firm, fibrous, adherent membrane ; and further, it is the distribution and location of these adhesions, not their extent, which determine the production of hydrocephalus. Adhesions encircling the mid-brain where it passes through the incisura tentorii interrupt the subarachnoid communication between the posterior and middle cranial fossæ, and thereby eliminate the cerebral subarachnoid space (the main area of absorption) from participation in the absorption of the fluid. Adhesions which obliterate the cisterna magna or those at the base of the brain will produce hydrocephalus as effectively. If this reasoning is correct, 'communicating hydrocephalus' is as much an example of an obstructive lesion as the intracerebral types of obstruction.

Returning, then, to our original conception of the possible causes of the disease, our experience leads us to the conclusion that increased formation of fluid may be excluded as of little practical importance, and that deficient absorption is not known to occur *per se*. Therefore, for practical purposes, we are only concerned with hydrocephalus which is due to congenital anomalies or to an obstruction to the circulation of the cerebro-spinal fluid. The latter type is naturally divided into two main groups in which the obstructive lesion is ventricular or extraventricular. The ventricular group is again divided into degrees according to the exact anatomical site of the lesion.

A More Suitable Classification.—On the grounds above stated, we suggest the following as a more suitable classification :—

	GROUP	DEGREE (Site of obstruction)
Hydrocephalus due to	Congenital anomalies	
	Ventricular (obstruction)	1. Between one lateral and 3rd ventricle 2. Between both lateral ventricles and 3rd ventricle 3. Between 3rd and 4th ventricles 4. In the roof of 4th ventricle
	Extraventricular (obstruction)	In the subarachnoid space

The above, we submit, is a simple, expressive, and accurate classification from the anatomical and physiological points of view. It is also very significant practically, for, as will appear later, each type has its distinctive and appropriate treatment.

In actual use we omit the term 'obstructive' entirely, and we speak, for example, of a ventricular hydrocephalus of the fourth degree, or of an extraventricular hydrocephalus.

THE ETIOLOGICAL PATHOLOGY OF HYDROCEPHALUS.

It is important to explain that the conclusions arrived at have been based entirely upon the observations made on the 21 cases under review, with the addition of certain other cases which, through the kindness of our colleagues, we have had an opportunity of studying.

1. **Congenital Hydrocephalus and the Conditions under which it is met.**—Under two varieties of conditions hydrocephalus has been met with at birth, and therefore the varieties may be described as examples of congenital types.

a. True Congenital Hydrocephalus.—There is a well-developed form in which the head is considerably enlarged at birth, so much so, sometimes, as to constitute an obstruction to delivery. This variety we have found to be associated with an error in the development of the central nervous system, which permits an escape of fluid from an open Sylvian aqueduct. The resulting hydrocephalus is of an external character, though there may be an associated dilatation of the ventricular spaces. It is not amenable to surgical treatment, and it is rarely compatible with post-natal life for any prolonged period.

b. The Variety of Hydrocephalus which Accompanies a Spina Bifida.—At birth attention is naturally directed to the spinal error, and the head condition may be overlooked, but we have satisfied ourselves that a certain proportion of spina bifida cases are accompanied by examples of congenital hydrocephalus insomuch as there is a ventricular dilatation present at birth ; we have confirmed this observation by ventriculography during life, and by post-mortem examination. If the spina bifida is operated on and the defect closed, the pre-existing hydrocephalus soon forces itself on one's attention by the rapid increase in the size of the head. This variety of hydrocephalus is of the extraventricular type in so far as there is no obstruction to the circulation of the fluid up to the point of its exit from the fourth ventricle.

These varieties of hydrocephalus (*a* and *b*) are the only ones which we believe to be congenital, and both of them are closely related to an error in the development of the central nervous system.

2. The Origin of Ventricular Hydrocephalus.—

a. Tumours as a Cause.—In a class by itself comes that group which owes the development of the hydrocephalus to the presence of a cerebral tumour. Theoretically a tumour which from its position presses upon any portion of the interventricular system may give rise to a hydrocephalus; practically, it is the cerebellopontine angle which is the usual situation of the neoplasm (*Fig.* 134). Its pressure is exerted upon the lower portion of the

FIG. 134.—Drawing from a specimen from a case of secondary hydrocephalus. The condition developed secondarily to a cerebellar tumour which occluded the lower part of the Sylvian duct, thus leading to a ventricular hydrocephalus of the third degree.

Sylvian aqueduct, and there is a resulting dilatation of the ventricular system above this level. Though in a very real way the hydrocephalus is a secondary development to the tumour, it is interesting that, in the examples of this condition which came under our care, the hydrocephalic condition clinically overshadowed the local tumour formation, and the clinical features which impressed themselves on the examiner were those of the ventricular hydrocephalus rather than the signs of the neoplastic condition.

As we have said, this type of obstructive hydrocephalus stands in a group by itself, and surgical interference is primarily directed towards the tumour; it does not rank as a primary hydrocephalus, and therefore it does not enter into a contribution of this description. There remains a large group of cases of ventricular hydrocephalus for which other causes must be found. Atresiae and adhesions constitute the remaining causal factors.

By the term 'atresia' we mean a narrowing or obliteration of a portion of the interventricular system, while by the use of the term 'adhesions' we imply that adhesions have formed at the base of the brain so as either to occlude the foramina in the roof of the fourth ventricle or to limit the circulation of the fluid in its immediate neighbourhood. From the etiological point of view both of these types have a common basis in so far as both varieties have an inflammatory origin, plastic or infective. We have not met with an atresia which could be accepted as an actual congenital error in the cerebral development—this is an important consideration. There is a wide variety of factors which may lead to the formation of adhesions, and certain causes are apparently more liable than others to produce the errors.

b. Birth Hœmorrhage as a Cause.—When investigating the case-histories it may be found that the birth was a difficult one, that forceps were employed, and that a good deal of trouble was experienced in the delivery of the head. In fact, in certain cases there was the likelihood that an intracranial hæmorrhage had occurred. In seven cases of the series under consideration a natal history of this sort was obtained, and the subsequent operative interference revealed the presence of a hæmorrhagic effusion in the membranes at the base of the brain; in certain of these the hæmorrhagic effusion was definitely invading the roof of the fourth ventricle, and it could be demonstrated that there was a resulting occlusion of the foramina normally present in the ventricle roof (*Fig.* 135). It would appear that a basal hæmorrhage of this description is more likely to occur when the forceps blades are applied in the sagittal axis of the head than in the coronal axis. It seems reasonable that the compression of a forceps blade beneath the occiput is more likely to produce a subtentorial hæmorrhage than forceps applied laterally.

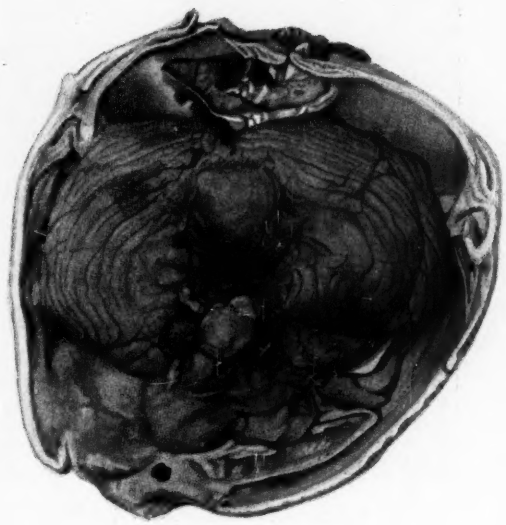

FIG. 135.—Drawing from a specimen of ventricular hydrocephalus of the fourth degree. The condition developed as the result of a basal birth hæmorrhage. There is a hæmorrhagic effusion in the cisterna magna, which has occluded the foramina in the roof of the fourth ventricle.

We possess very definite evidence that an intracranial hæmorrhage produced at birth is liable to be followed by a hydrocephalus if the location of the hæmorrhage is subtentorial in its distribution. These remarks apply at this stage only to ventricular hydrocephalus, but we shall allude to the subject again in relation to the extraventricular type.

c. Infective Meningeal Conditions as a Cause.—It is possible that we underestimate the degree of occurrence of infective meningeal conditions in the early period of life: the imperfect ossification of the base of the skull may explain a greater liability to infection from the extracranial regions at this stage than in later life. At any rate, during infancy there is a definite proportion of children who suffer from inflammatory meningeal conditions. The infections are not necessarily fatal; some of them are so slight as scarcely to claim close attention, more especially as they may be overshadowed by more urgent general symptoms, yet the congestion and effusion which they have induced may be sufficient to give rise to an occlusion of the route of the ventricular circulation, and subsequently to hydrocephalus.

An interesting example illustrative of this point is borne out by the following case-history :—

Case 1.—J. S. (6½ months). About six weeks before admission to hospital the baby had been much in contact with a number of cats who were suffering severely from distemper. The child took an illness which closely resembled the distemper of animals—temperature, coryza, discharge from nose and eyes. The child's uncle is an authority on veterinary matters, and he had no doubt that the child's illness was a direct infection from the animal source. Within ten days of the onset of the illness the child developed what clinically resembled a mild meningitis, with head retraction, vomiting, and eye squint. These symptoms lasted a few days, and a complete recovery then seemed to follow. About two weeks later it was noticed that the head was beginning to enlarge, and a hydrocephalus rapidly developed.

Investigation showed the hydrocephalus to be an obstructive one due to occlusion of the foramina in the roof of the fourth ventricle. So rapid was the enlargement of the head that operative interference was impossible. The child died, and subsequent examination demonstrated signs of a former basal meningitis, which had resulted in occlusion of the ventricular foramina.

FIG. 136.—Two examples of syphilitic hydrocephalus. Both cases were ventricular in type.

FIG. 137.—Drawing from a specimen of syphilitic basal meningitis. The condition has led to closure of the foramina of Magendie and Luschka, and to a resulting ventricular hydrocephalus of the fourth degree.

In certain cases of the series under consideration we believe that a former subacute basal meningitis was the essential causative factor.

d. Congenital Syphilis as a Cause.—In certain cases of congenital syphilis there may be an associated chronic inflammatory thickening of the cerebral meninges (*Fig.* 136). Such a change is most marked at the base of the brain (*Fig.* 137), and the more vascular pia-arachnoid is affected to a greater degree than the less vascular dura mater. It is in the tissues around the cisterna magna and the cisterna basalis that the plastic and adhesive specific meningitis may be most evident. We confess we have been surprised to find what a relatively large proportion of hydrocephalics are victims of congenital syphilis and show a positive Wassermann reaction. The meningeal changes may develop in the child who otherwise does not show the general stigmata of the disease—in fact, it would appear that it is in the ill-defined and indefinite types of the disease that the meningeal changes are most in evidence.

It has further been our experience that in the atresic forms of hydrocephalus, where

the obstruction to the circulation of the cerebrospinal fluid is situated above the point of exit from the fourth ventricle, congenital syphilis is such a common concurrent condition that we believe that a considerable proportion of the atresiæ are specific in origin. The point is one of considerable importance, because in certain cases in which the origin of the hydrocephalus was recognized as being specific, we were able to arrest the progress of the disease by means of antisyphilitic remedies without operative interference.

We believe that the possible origins of ventricular hydrocephalus may be summarized into three classes—according to whether it is dependent upon intracranial birth hæmorrhage, former subacute inflammatory meningeal condition, or the leptomeningitis which develops in association with congenital syphilis.

3. **The Etiology of Extraventricular Hydrocephalus.**—Until a recent publication of Dandy's work no satisfying explanation had been offered of the origin of the extraventricular type of hydrocephalus. It is clear that no obstruction exists up to and including the points of exit of the fluid from the fourth ventricle. The possibility that there is an over-production of cerebrospinal fluid has never been established, and, if this is not the fault, the only other possible explanation is a diminished absorption of the cerebrospinal fluid. The difficulty has been to explain the obstacle which exists to the absorption of the fluid.

Dandy's view as to the anatomical lesion responsible for this type has already been given, viz., pia-arachnoid adhesions which shut off the absorbing area of the cerebral subarachnoid space from the posterior cranial fossa.* In our series of cases, six have been examples of the extraventricular variety, and we have had an opportunity of satisfying ourselves that the explanation brought forward by Dandy has a great deal to recommend it. Certainly in these cases there is an extensive obliteration of the subarachnoid space by adhesions. They are best illustrated at autopsy, and, to demonstrate them efficiently, the brain should be removed with the dural covering, if possible, intact. From the base of the child's skull the dura can be removed with greater facility than is the case in the adult, and subsequent dissection will then demonstrate that the normal pia-arachnoid membrane is replaced in these cases by an opaque adherent membrane which extends over the region of the cisterna magna and basalis, around the cerebellar hemispheres, and downwards to the foramen magnum. Adhesions in this region must constitute a very real obstruction to the circulating cerebrospinal fluid, and, once the backward pressure has caused reaction and internal hydrocephalus has begun, a vicious circle is actually in existence, because, as the cerebral distention increases, the close contact of the cerebral tissues with the meninges and skull, and, more especially, with the unyielding base of the skull, further increases the obstruction to the upward circulation of the cerebrospinal fluid. The actual origin of the adhesions in extraventricular hydrocephalus is similar to that already discussed in relation to the ventricular type, with the proviso that birth hæmorrhages probably do not play a part in the first-mentioned variety: basal meningitis, simple or specific, is the more likely origin.

SOME POINTS IN THE MORBID ANATOMY OF HYDROCEPHALUS.

We have dealt with the more important points in the etiological pathology of the condition, and it remains to review the more outstanding characteristics of the morbid anatomy. The essential feature is a distention of the ventricular system with cerebrospinal fluid. The distribution of the distention will necessarily depend on the type of hydrocephalus. In the extraventricular type the complete ventricular system is involved; in the ventricular variety the distention will depend on the situation of the obstruction.

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* Dandy states that he has produced communicating hydrocephalus experimentally by encircling the mid-brain with a strip of gauze saturated in iodine, and so inducing adhesions. *Ann. of Surg.*, 1919, lxx, 129.

The following table shows the distribution which has come under our notice.

Table 1.—THE TYPES OF HYDROCEPHALUS IN THE SERIES UNDER REVIEW.

Extraventricular type	..	6 cases	
Ventricular type, 1st degree	..	0 ,,	
,, ,, 2nd ,,	..	0 ,,	
,, ,, 3rd ,,	..	7 ,,	(including 2 tumour cases)
,, ,, 4th ,,	..	8 ,,	
Total	..	21 cases	

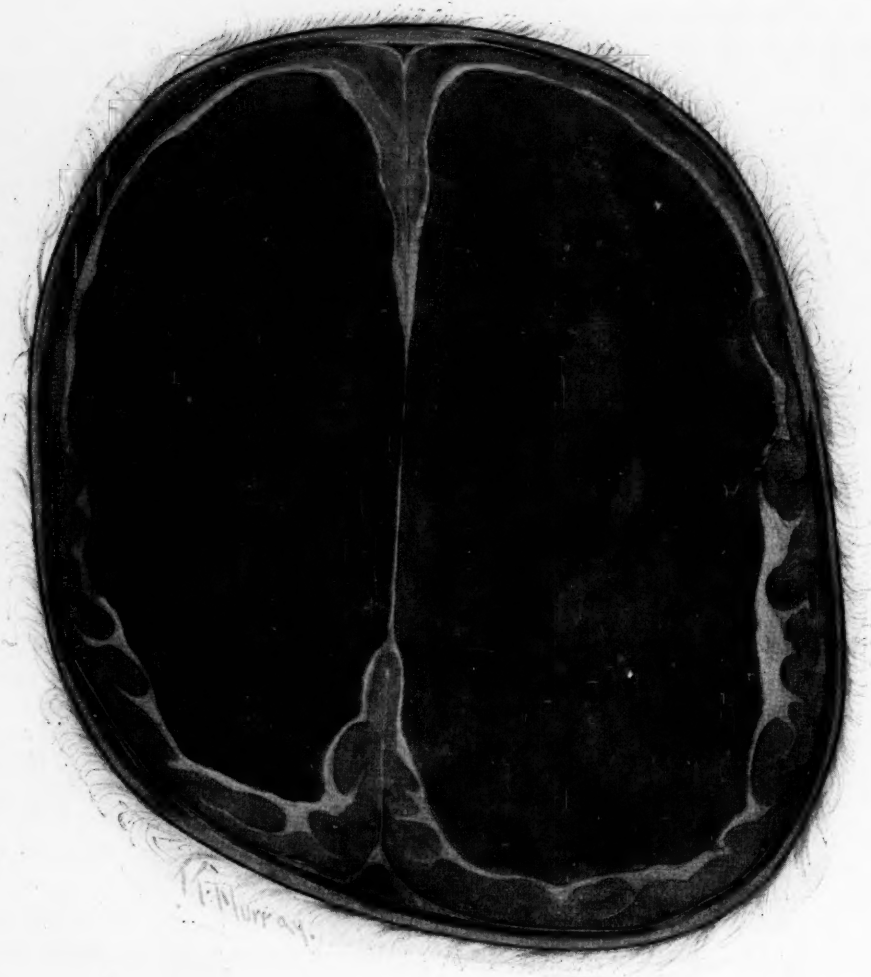

FIG. 138.—A frozen section through the head of a ventricular hydrocephalus. It illustrates the extreme degree of destruction of the white matter. (*Dr. Thomson's case.*)

Our experience has been that the ventricular type is more common than the extra-ventricular type in a proportion of about 3 to 1, and of the ventricular type the fourth degree of obstruction, i.e., in the roof of the fourth ventricle, is the most common in a proportion of 8 cases out of 15.

The increasing distention of the ventricular cavities leads to a progressive thinning of the cerebral tissues, and it is interesting that the disappearance of the cerebral substance is at the expense of the white tissue—even in the most advanced example of the disease a zone of grey tissue of approximately normal thickness exists (*Fig.* 138). The cerebral

sulci become opened out, and sometimes they disappear; this change is most marked in the frontal region of the brain. The fontanelles, the sutures, and the imperfect ossification generally of the cranial vault encourage an enlargement of the dome of the skull, while the more unyielding base is not correspondingly affected. It is this disproportion which gives the characteristic clinical appearance of hydrocephalus, and which also explains the unlikelihood of there being much displacement of the medulla downwards into the foramen magnum. We shall allude again to the importance of dealing with these cases before the destruction of cerebral tissues becomes marked; the whole basis of successful treatment will depend on its early inauguration. As long as the basal ganglia remain intact life continues, and, as the distention follows the line of the yielding skull in an upward direction, these ganglia are wonderfully preserved from pressure until a late stage; but, from the point of view of making operative interference worth while, close attention should be paid to the degree of destruction of cerebral white tissue which is proceeding.

A puzzling point in pathology is opened up when we attempt an explanation of a variety of hydrocephalus which is accompanied by a complete occlusion of the ventricular system, and yet the hydrocephalus has been spontaneously arrested. Through the kindness of a colleague we have had an opportunity of examining the case-records of two examples of this puzzling condition. The first and the more impressive case was that of a young adult, age 25 years, who had died suddenly from what was thought to be a cerebral hæmorrhage. There had been a complaint of giddiness and headache with some vomiting. Two hours later unconsciousness supervened, the breathing became stertorous, and within a short period he was dead. In the previous history there was no definite account of serious illness; he had been recognized as a delicate man, nervous and highly-strung, constantly subject to headaches and attacks of migraine. The head was not unusually large, and on superficial examination there was nothing to suggest a hydrocephalus. On autopsy a peculiar state of affairs was discovered. The convolutions were flattened and relatively few in number, the entire ventricular system was dilated, and the roof of the fourth ventricle was completely occluded by a dense fibrous membrane. No trace could be discovered of the normal foramina, and tests applied showed that the intraventricular fluid had apparently no communication with the subarachnoid fluid along the usually recognized channels.

The second case occured in a boy, age 8 years. We have no knowledge of the previous clinical history, but the autopsy specimen which we were permitted to examine showed a long-standing occlusion in the roof of the fourth ventricle, which, as far as we could discover, must have completely isolated the intraventricular from the extraventricular fluid.

The importance of cases such as these is that they would appear to indicate one of two possibilities :—

1. Either there are intraventricular media for the absorption of cerebrospinal fluid with which we are at present unacquainted; or

2. Under certain conditions the isolation of the intraventricular fluid by occlusion of the foramina leads to a greatly diminished production of cerebrospinal fluid; and further, it would seem to presuppose that there are extraventricular sources of production of cerebrospinal fluid, for in both of the above cases cerebrospinal fluid was present in the subarachnoid spaces.

It is clear, at any rate, that cases such as these indicate that there are possibilities in the physiology, or at least in the pathological physiology, of the cerebrospinal fluid circulation with which at present we are not completely acquainted.

There are many other details in the pathology of hydrocephalus to which we have not alluded; we have purposely dealt only with those which have a bearing upon the surgical treatment of the disease.

CERTAIN CLINICAL FEATURES OF THE DISEASE.

Question of Sex and Age.—There is nothing to be learned from a consideration of the sex; in the series under review there was a curious similarity in the sex occurrence, the figures being respectively 11 males and 10 females.

The age at which the cases came under surgical notice is shown in the following table :—

Table 2.—The Age Occurrence.

	Months												Years			
Age ..	1	2	3	4	5	6	7	8	9	10	11	12	2	3	4	5
Cases ..	–	2	3	5	1	1	2	1	2	–	–	1	1	2	–	–

The majority (18) of the cases were under one year old, 1 child was a year and a half, and 2 of the cases were between two years and three. No cases appeared at a later age than three years.

The Clinical History.—In certain cases the statement was offered that the parents noticed the head to be somewhat enlarged at birth, but it is doubtful if any real weight can be attached to this observation. It is clear that in no case was the head of such a size at birth as to offer any difficulty to delivery. There was no case, therefore, which would justify the qualification of being congenital in the sense that the signs of the disease were definitely present at birth. The two examples of true congenital hydrocephalus which have been mentioned are not included in this summary.

In certain instances it was remarked that the scalp veins were unusually prominent, and this feature was observed before any definite cranial enlargement was apparent.

As the head increases in size, the enlargement at first is a gradual one ; but after a definite point is reached the distention of the head progresses more rapidly. Dandy[10] offers an observation which appears to contradict this statement, for he believes that the production of cerebrospinal fluid diminishes as the pressure within the ventricles increases ; but clinically we are convinced of the truth of the point which we have made. For example, such an observation as this was repeatedly made :—

E. H.—

First observation,	April	10,	circumference of head		$17\frac{3}{4}$	inches
Second „	May	12	„	„	18	„
Third „	June	15	„	„	$18\frac{3}{4}$	„
Fourth „	July	10	„	„	$21\frac{1}{2}$	„
Final „	July	30	„	„	23	„

During the last six weeks of observation the head increased by $4\frac{1}{4}$ inches, as compared with an increase of one inch during the first two months of observation. It would seem that, after a definite point is reached, the tension exerted by the skull is so reduced that the underlying cerebral distention is less restricted than before. There is no clinical evidence that there is a diminished production of cerebrospinal fluid as the tension increases.

As the head enlarges the axis of the eyes is displaced downward, so that the sclerotics appear constantly underneath the upper lids. There is often a well-marked strabismus. The occurrence of nystagmus is an unusual feature. In the later stages of the disease sluggishness of the pupils and atrophy of the optic nerve are sometimes present. The mentality of the children ranges between extreme idiocy and normal intelligence. Most of the patients are feeble-minded and apathetic ; if old enough, they have difficulty in speaking. Motor disturbances are usually well-marked, and manifest themselves in spasms, paresis, unusual rigidity, and tremors ; the lower extremities are more severely affected than the upper. Sometimes the spasms and paresis are more marked on one side than on the other. The reflexes are increased. Twitching of individual groups of muscles and general convulsions may occur. Hydrocephalic children usually present a delicate appearance, they are pale and emaciated, with a senile expression. On account of the weight of the head its support is difficult, and therefore it is often bent forwards or thrown backwards. These children generally cry a good deal, and they do not readily put on weight. The appetite is not bad, but digestion is usually retarded.

It is sometimes remarkable how few general symptoms may exist in a hydrocephalus of the most marked degree. The infant a section through whose head is illustrated in *Fig.* 138 was one of this type. It can be recognized how very marked was the atrophy of nerve-tissue, and yet, to within forty-eight hours of death, the intelligence was such that the child recognized its mother, while there was very little evidence of paralysis or rigidity of the superficial musculature.

THE PHYSICAL EXAMINATION OF THE CASE.

In the majority of cases it is sufficiently obvious that a hydrocephalus is present, but further examination is required if the case under review is to be efficiently classified ; and efficient classification necessarily involves that an attempt be made to answer three questions : 1. *Does any evidence exist which would indicate the possible origin of the disease?* 2. *To what variety of hydrocephalus does it belong? Is it ventricular or extraventricular in type?* 3. *If it is ventricular in type, at what level does the lesion exist which is responsible for the hydrocephalus?*

The physical examination is directed towards supplying an answer to each of these individual queries so far as is possible. The answers having been given, classification is possible, and an intelligent treatment may be planned.

1. **The Origin of the Disease.**—If this question can be answered, the information will be obtained by careful questioning of the parents, a full case-history, and general examination of the child. Attention is specially paid to three possibilities—the occurrence of a syphilitic infection ; the infliction of an injury to the skull, such as may have produced an intracranial hæmorrhage ; and the history of a previous meningeal or encephalic infection. A fourth possibility exists, namely, the possibility of the coincident existence of a cerebral tumour.

In certain cases the evidence obtained is sufficiently strong to enable one to estimate with a degree of certainty the origin of the hydrocephalus, as, for example, in the specific types and the post-infective meningeal conditions.

A considerable proportion of cases, however, necessarily remain in which no definite idea can be formed of the etiology, and such a lack of knowledge is not after all serious, because an answer to the question is not essential in deciding on the line of treatment to be adopted. If possible, however, an attempt should be made to classify the case according to its etiology.

2. **The Type of the Hydrocephalus.**—According to Dandy's classification the question would be put : Is the hydrocephalus obstructive or communicating in type? But we have explained our reasons for preferring to express the varieties as ventricular or extraventricular.

Recognizing that practically all cases of hydrocephalus are obstructive in type, it is necessary to demonstrate whether the obstruction exists somewhere in the ventricular system up to and including the point of exit of the fluid from the fourth ventricle, or whether it exists in the subarachnoid spaces (communicating). Three procedures are followed in demonstrating the answer to the question :—

a. Lumbar Puncture.—Lumbar puncture may give a suggestive result, but not a definite answer to the question. An intraventricular hydrocephalus may show low tension in the spinal fluid, while an extraventricular hydrocephalus may show an increased tension ; but variations exist, and occasionally the sequelæ are reversed. Therefore, while this investigation may be suggestive, it cannot be accepted as absolute.

b. Intraventricular Injection of an Indicator, with Investigation of the Cerebrospinal Fluid.—Following Dandy's recommendation, we have used phenolsulphonephthalein as an indicator. It is important that the solution employed should be neutral, and we have employed the preparation supplied by Martindale. Inattention to the detail of the neutrality of the fluid may result in a sharp reaction characterized by temperature and signs of cerebral irritability.

The technique of injection is simple : one or other lateral ventricle is punctured with

the needle of a 'record' syringe, the syringe holding 1 c.c. of the phenolsulphonephthalein solution. When the ventricle has been entered 1 or 2 c.c. of cerebrospinal fluid are removed into the syringe barrel and allowed to mix with the indicator. The mixture is then injected into the ventricle, and the needle withdrawn. After an interval of time lumbar puncture is done, and the spinal fluid is allowed to pass into a test-tube containing a few drops of 25 per cent sodium hydrate solution.

Dandy recommends that thirty minutes should be allowed to elapse before the lumbar puncture is done; in our experience such a long interval is unnecessary. If the indicator can be recovered in the spinal fluid it will become obvious within five minutes, and sometimes even less.

By the recovery of the indicator (as evidenced by the pink coloration of the cerebrospinal fluid when it comes into contact with the sodium hydrate) it may be accepted that the hydrocephalus which exists is not due to an intraventricular obstruction up to and including the point of exit of the fluid from the fourth ventricle. In other words, the recovery of the indicator means an extraventricular hydrocephalus (communicating type —Dandy), while the non-appearance of the indicator in the spinal fluid may be taken as demonstrating an intraventricular hydrocephalus (obstructive type—Dandy).

c. The Recovery of the Ventricular Injection Substance from the Urine.—It is said that normally the amount of fluid absorption which occurs in the ventricular system is negligible; it is estimated at less than 1 per cent in two hours. The bulk of absorption within the skull occurs in the subarachnoid spaces, from which area as much as 40 to 60 per cent of an introduced fluid is excreted after two hours' interval. Based on these considerations the recovery of phenolsulphonephthalein from the urine subsequent to its injection into the ventricles becomes a matter of importance, for if a ventricular hydrocephalus exists practically none of the indicator will be recoverable within a reasonable time (two hours), while if an extraventricular hydrocephalus is present, the indicator will be recoverable, though not to the same degree as in a normal case.

We have not put this method of investigation into routine use. It expresses the same knowledge as is gained from an examination of the spinal fluid, while its demonstration is a matter of greater difficulty. Therefore we have relied on answering the question regarding the type of hydrocephalus by the second method of investigation, the examination of the spinal fluid after the intraventricular injection of an indicator.

Investigation by these methods, and more especially by the second, carries the observer a step forward, in so far as he is now able to classify the case of hydrocephalus into a ventricular or an extraventricular type. If it should happen that the case is an extraventricular one, we have not considered it necessary to proceed further with the routine examination.

By the injection of air into the spinal theca Dandy[11] has demonstrated after *x*-ray examination the actual location of the adhesions which are responsible for this type of hydrocephalus. He has shown the arrest of the air at the base of the brain and its absence from the cerebral sulci. All these points are demonstrable in extraventricular hydrocephalus, but their demonstration does not aid us in the question of treatment, at least, with the methods at present available to us.

3. **The Level of the Lesion.**—If, however, our original investigation has shown that the hydrocephalus is a ventricular one, further details of knowledge must be available before an intelligent operative treatment can be undertaken. The degree of hydrocephalus must be known, the situation of the obstruction must be localized: this knowledge is gained by the method of ventriculography.

The Technique of Ventriculography.—Cerebral diagnosis and cerebral surgery would benefit if it were possible to introduce into the ventricular system a fluid opaque to the action of *x* rays. Hitherto no fluid has been suggested which fulfils the necessity of opacity and yet does not irritate the delicate structure of the ependyma and choroid plexuses. The necessity of the non-irritating character of the fluid is all the more important when we consider that in intraventricular hydrocephalus the fluid may be isolated within the ventricles for a prolonged period of time—in fact, until it is artificially liberated or removed.

In the absence of a safe and yet efficient fluid, air has been employed, and in young children, in whom the ossification of the skull is not too advanced, it delineates with remarkable distinctness the ventricular outlines. The method is simple. One lateral ventricle is punctured, and to the needle an accurately fitting 'record' syringe of 20-c.c. capacity

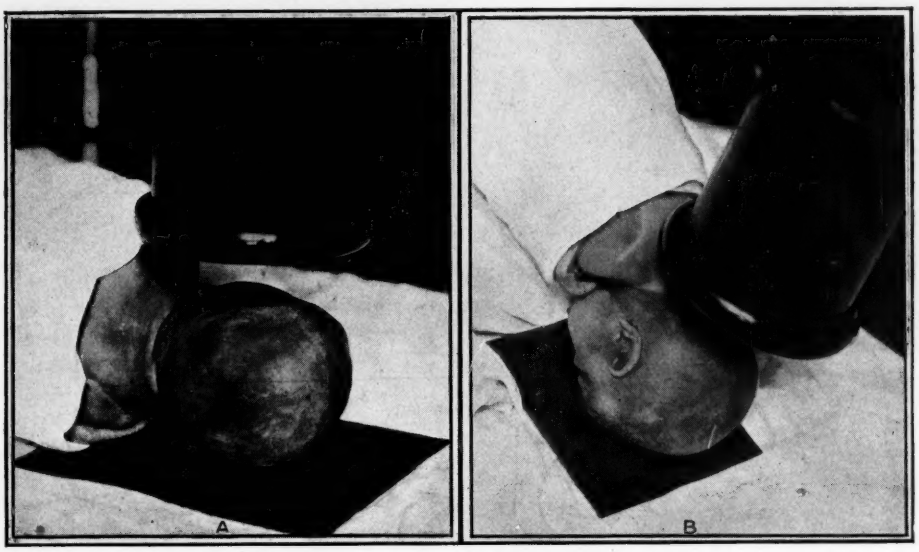

FIG. 139.—The position of the head for ventriculography. A, To record the outline of the left lateral ventricle. B, To record the outlines of the third and fourth ventricles.

is fitted. The cerebrospinal fluid is slowly removed from the cavity of the ventricle, and when 20 c.c. are evacuated, a corresponding amount of air (20 c.c.) is injected into the ventricle, using the empty 'record' syringe for this purpose. The joint between needle and syringe is covered with sterile vaseline to prevent an escape of air at this point.

In a hydrocephalus of moderate size (18 to 19 inches in circumference) we remove 70 to 80 c.c. of fluid, replacing the fluid with a corresponding quantity of air. The removal of the fluid and the introduction of the air must be carried out in small alternating amounts, as the sudden removal of a large quantity of fluid without the supporting influence of the air might induce a cerebral œdema, and possibly an intraventricular hæmorrhage. After the introduction of the air, a hollow note can be elicited over the ventricle, and on movements of the head air may be heard to gurgle from one portion of the ventricular system into another.

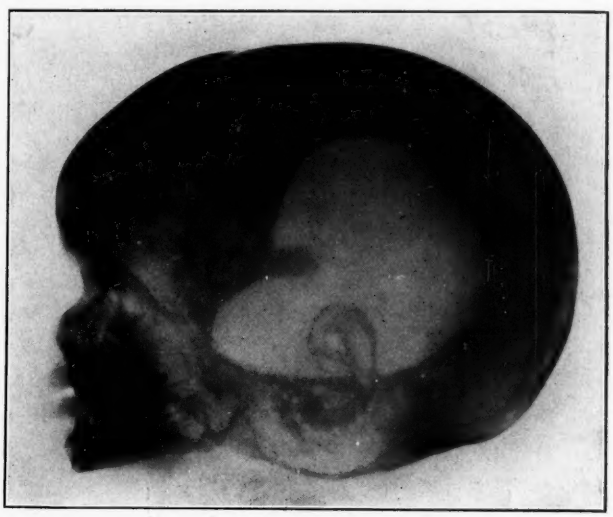

FIG. 140.—Ventriculogram showing outline of dilated lateral ventricle filled with air. (Lateral position of head.)

Radiograms are now taken with the head in three different positions—right and left ateral, and with the head hanging downwards so that the skull base is at the highest level (*Fig.* 139). The first plate will show the outlines of one lateral ventricle (*Fig.* 140), the

second will demonstrate the opposite ventricle—assuming that the foramina of Monro and the third ventricle are patent—while the third plate will illustrate the third and fourth ventricles and the iter.

FIG. 141.—Topography of normal lateral ventricle.

Such views of the ventricular system would probably be very difficult to demonstrate in the normal brain (*Fig.* 141). We have never made the attempt, but in the hydrocephalic, where the ventricular system is distended, definite and clear representations can be obtained. The value of the examination lies in the fact that it will locate the level at which the obstruction exists.

We have not had an opportunity of observing the appearance of an obstruction in the foramen of Monro; iter obstructions are characteristic (*Fig.* 142); obstruction in the roof of the fourth ventricle is also distinctive (*Fig.* 143), for, though ventriculography of an extraventricular hydrocephalus gives a somewhat similar representation, it can be otherwise excluded as shown above.

The introduction of air into the ventricles may appear to be a somewhat heroic proceeding in the investigation of a case of hydrocephalus, but actually the method is practically devoid of risk; certainly with the cases which

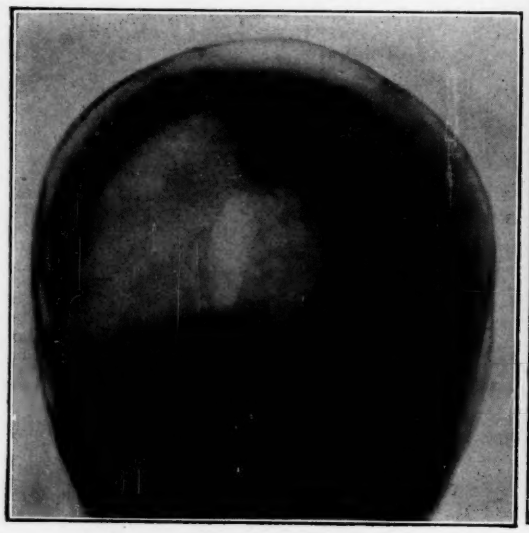

FIG. 142.—Ventriculogram showing outlines of dilated left lateral and third ventricles. The air has failed to enter the aqueduct of Sylvius, indicating an obstruction at this site—ventricular hydrocephalus of the third degree. (Inverted position of head.)

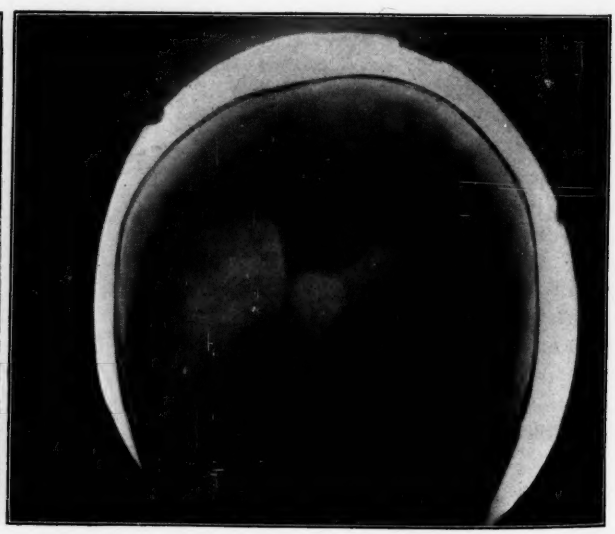

FIG. 143.—Ventriculogram showing outlines of dilated left lateral, third, and fourth ventricles. Note the air in the right foramen of Monro, and the bulging roof of the fourth ventricle. Obstruction at the roof of the fourth ventricle is indicated. Ventriculogram in conjunction with the coloured indicator test. (Inverted position of head.)

have come under our care we have had no anxiety. Occasionally there is a reactive rise of temperature, but it is not excessive, and it soon subsides.

A Survey of the Clinical Examination.—A successful clinical examination will have thrown some light on three aspects of the disease: (1) The possible origin; (2) The type —ventricular or extraventricular; (3) The degree of the ventricular type. With these facts at our disposal the consideration of the treatment may reasonably be discussed.

TREATMENT.

The Importance of Early Treatment.—If the efficient treatment of hydrocephalus is to give us satisfactory results it must be carried out before the expansion of the head has become too marked. There is nothing to be gained from operating on a child if the white matter of the brain is already reduced to a shell. No definite limit can be fixed; it must be left a good deal to the decision of personal judgement; but we have found that an increase in circumference measurement up to 3 inches above the normal is within the range of satisfactory post-operative recovery. Above this figure we enter the range of unsatisfactory results, and with every degree of increase the probability of improvement diminishes.

Various Lines of Treatment hitherto Suggested.—Kausch,[12] in the course of a most exhaustive article, details the various procedures which have hitherto been tried in the treatment of hydrocephalus. We append the following tabular account; there is nothing to be gained by a more detailed recitation of the methods, and those who are interested are referred to Kausch's contribution (*see also* Haynes[13]).

The following methods have been suggested or actually used in the treatment of hydrocephalus :—

1. Intermittent drainage
   - i. Of lateral ventricle
   - ii. Of the spinal canal
   - iii. By puncture of the corpus callosum
2. Continuous drainage
   - *A*. Of the lateral ventricle
     - i. To the surface
     - ii. To subcutaneous tissue
     - iii. Into subdural or subarachnoid spaces
     - iv. Into the peritoneal cavity
     - v. Into the temporal vein
     - vi. Into the superior longitudinal sinus
   - *B*. Of the spinal canal
     - i. To surface
     - ii. Into retroperitoneal tissues
     - iii. Into peritoneal cavity
   - *C*. Of the subarachnoid space (fourth ventricle)
   - *D*. Of the cisterna magna into the cranial sinuses
3. Indirect treatment (carotid ligatures)
4. Other methods of treatment, such as by a seton, injection of iodine, galvanopuncture, compression of head, and by drugs

With such a variety of methods of treatment available, the conclusion may be come to that no single one has proved efficacious. Incomplete methods of investigation and an imperfect knowledge of the etiological pathology have been responsible for this unsatisfactory state of affairs.

The Essential Difference in Treatment between the Ventricular and the Extraventricular Types.—It is obvious that a very clear distinction must be drawn from the operative point of view between the ventricular and extraventricular varieties. Both are certainly obstructive in nature; but, while one (ventricular) is localized and accessible, the other (extraventricular) is diffuse, and practically inaccessible.

If the hydrocephalus is of the ventricular variety—that is to say, if there is an obstruction at some portion of the ventricular system proximal to and including the roof of the fourth ventricle—experience has shown that the only efficient way of treating the hydrocephalus is by removing the obstruction, and so opening up the normal passage for the circulation of the cerebrospinal fluid.

In the extraventricular variety the problem is more difficult; but we discuss later the possibilities of treatment of this variety.

The Operative Treatment of Ventricular Hydrocephalus.

All examples of ventricular hydrocephalus, with the exception of the very rare first and second degrees, are operated on by the occipital route. We have not had an opportunity of treating a case of the first or second degree, and would therefore refer the reader to Dandy's observations on this point. The essential feature of the suboccipital operation is to expose that portion of the ventricular system which is most accessible, namely, the roof of the fourth ventricle, and through this region to deal with or remove the obstruction which exists.

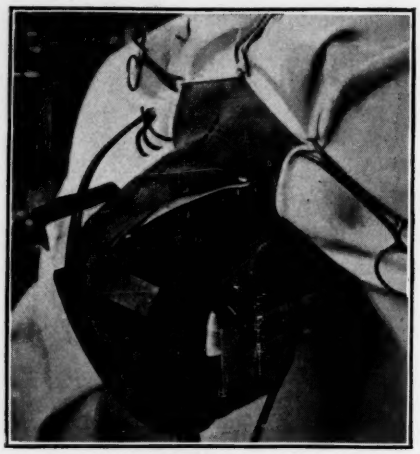

FIG. 144.—*The suboccipital operation for hydrocephalus*: 1.—The position of the head upon the head-rest is shown. The incision is indicated by the dotted line. The self-retaining retractor has been fixed in place by a rubber band round the head. The anæsthetic is being administered by the intrapharyngeal method.

Preliminaries and Anæsthesia.—The operation should be undertaken while the child is in as fit a condition as possible. Nothing should be attempted if there is any suspicion of cold or bronchitis. Throughout the operation, which may be a lengthy one, the child is kept warm—an arrangement like a sleeping bag made of gamgee tissue meets the requirement. The child is placed on its face with the head flexed on the chest and, to ensure a satisfactory position, we have adopted a special head-rest which supports the head in the correct position and permits the administration of the anæsthetic and yet does not interfere with the respiratory movements (*Fig.* 144).

Intrapharyngeal ether has been the anæsthetic of choice, the anæsthetic being administered by a catheter introduced through the nostril.

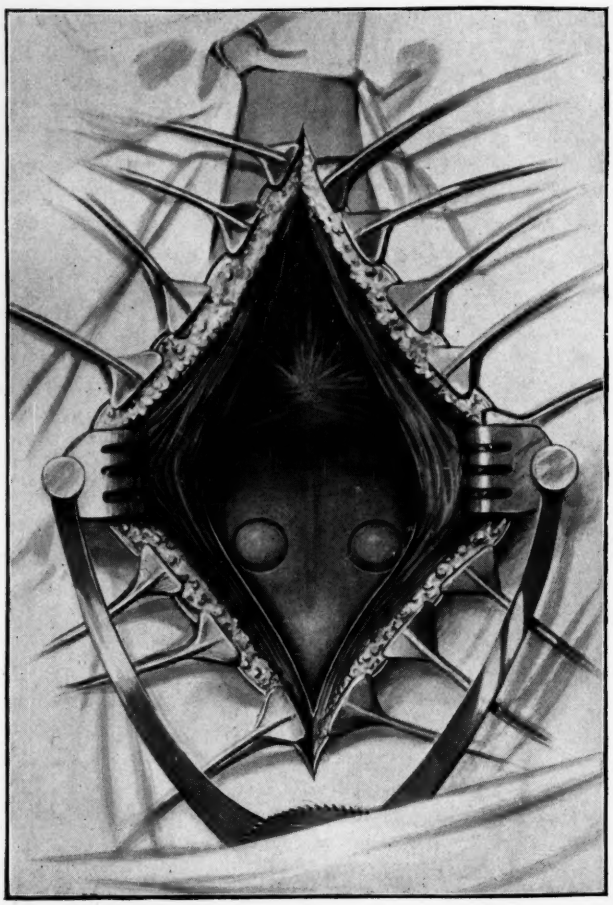

FIG. 145.—*The suboccipital operation*: 2.—The vertical muscles of the suboccipital region have been split in the middle line, down to the bone. The periosteum has been detached from the occipital bone. These structures are retracted. The spine of the axis, with the attachments of the deep muscles, is exposed. The bone has been perforated with the burr over either cerebellar hemisphere.

The Exposure of the Roof of the Fourth Ventricle.—A mid-line incision is made, extending from the external occipital protuberance downwards to the level of the 7th cervical spine. In the earlier cases we employed a crossbow incision, but it involved an unnecessary amount of hæmorrhage, and the access which it provides is not appreciably greater than

that afforded by the straight mid-line incision. The incision is deepened through the fibrous intermuscular space, exposing the mid-line of the occipital bone and the spines of the upper cervical vertebræ (*Fig.* 145). The muscular attachments are separated outwards, and such free separation is possible that we have not found it necessary to carry out any transverse division of the muscles. We believe that any transverse section of the muscles is to be avoided ; the upper portions of the muscles in the child are flimsy, and they are easily so bruised and destroyed as to make their re-attachment difficult. From the occipital bone the separation may be carried out subperiosteally ; the trapezius need not be disturbed, but the complexus, the rectus capitis posticus minor, the superior oblique, and the rectus capitis posticus major are separated outwards to the line of the occipital artery ; this vessel is not in view, as it is under cover of the separated muscles. The result is an exposure of the occipital bone, vertically from the 'linea suprema' to the margin of the foramen magnum, and laterally from the right to the left occipital artery line.

Two trephine openings are now made, one on each side of the mid-line, so as to avoid the occipital sinus. The trephine openings are made with a Hudson's drill, and enlarged with a burr. With a rongeur forceps a crescentic area of bone is removed, the concavity of the crescent being at the posterior margin of the foramen magnum, while the convexity is half an inch within the area of the muscular separation. The removal of the posterior margin of the foramen magnum is an important point. During this stage of the proceedings bleeding is troublesome, more especially at either side of the foramen magnum ; it is arrested by the use of bone wax and by gauze plugs. Special care is required as the area of bone over the occipital sinus is removed, and the downward removal of bone should not be carried so far as to damage the emissary veins which pierce the bone a quarter of an inch from the lateral angles of the foramen magnum. The upward removal of bone need not expose the lateral sinuses.

FIG. 146.—*The suboccipital operation* : 3.—The bone defect has been completed and the posterior margin of the foramen magnum removed. Ligatures have been applied to control the occipital and marginal sinuses. The dura mater has been incised on either side of the mid-line.

The dura of the cerebellar fossa appears in view, and an estimation can be formed of the degree of intracranial pressure which exists by the amount of dural bulging which is present. If there is considerable tension we now puncture one lateral ventricle and remove a sufficiency of fluid to relieve appreciably the pressure which exists.

The next stage is the control of hæmorrhage from the occipital sinus and from the marginal sinuses. This is efficiently done by including the various sinuses in sutures carried on round needles. Four ligatures are applied, one at each extremity of the occipital sinus and one around each marginal sinus as far forward as the ligature can conveniently be placed (*Fig.* 146).

The dura is now opened over each cerebellar hemisphere, and it is carefully separated inwards until the falx cerebelli is reached. This structure is divided about its centre with a fine pair of blunt-pointed scissors, and immediately there is a retraction of the divided dural tissue and an exposure of the posterior surface of the cerebellar hemisphere covered by the pia-arachnoid tissues. Additional space can be obtained, when necessary, by

extending short vertical incisions upwards from either extremity of the transverse incision, so as to form an upper dural flap. A special retractor, having a cup-shaped surface for each cerebellar hemisphere and a central notch which is occupied by a small electric lamp, is now introduced beneath the cerebellum, and that organ is gently displaced upwards. The displacement must of course be regulated with the greatest delicacy and care. A space is exposed which lies between the under surface of the cerebellum and the posterior surface of the medulla, and which is bridged across by strands of arachnoid tissue; this is the cisterna magna (*Fig.* 147). If the hydrocephalus is of the fourth degree, the obstruction having occurred in the roof of the fourth ventricle, and if it is of an adhesive type, the result of a birth hæmorrhage or a former basal meningitis, this space may be largely obliterated by fibrous adhesions and hæmorrhagic extravasations. If such is the case, great care must be exercised in the separation of the adhesions, because, owing to the distention of the ventricles, the roof of the fourth ventricle is displaced backwards, and is torn before one is aware of its proximity. The roof of the ventricle should now come into view. If it is a bulging tent-like structure with definitely thickened texture and obvious obliteration of its foramina, it may be accepted that it is the site of the obstruction of the circulation of the cerebrospinal fluid, and be dealt with accordingly. It is our practice in such cases to remove a diamond-shaped area of the tela choroidea with fine spring forceps and eye scissors fitted with long-angled handles (*Fig.* 148).

FIG. 147.—*The suboccipital operation*: 4.—The dura mater has been completely opened, and the upper flap allowed to retract. The cerebellar hemispheres and cisterna magna are exposed.

The Relief of an Iter Obstruction.—If it should happen that the hydrocephalus is of the third degree, the obstruction existing in the iter, the operation has to be carried a stage further. In the third degree the fourth ventricle is not distended, and the obstruction in the iter is generally at one or other extremity. To gain access to the iter we follow the technique which Dandy first recommended. A small nasal speculum is inserted beneath the inferior vermis of the cerebellum, and, if further access is necessary, the vermis is split in the mid-line with a fine-bladed knife. The edge of the inferior medullary velum comes into view, and,

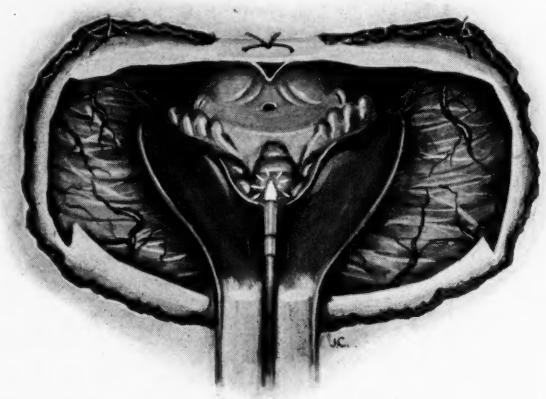

FIG. 148.—*The suboccipital operation*: 5.—The cerebellar retractor has been introduced and the cerebellum displaced upwards and its lobes laterally. The roof of the fourth ventricle is in view, illuminated by the small lamp. The foramina of Magendie and Luschka are seen (if not obliterated by adhesions).

if the tela choroidea forming the lower half of the ventricular roof has not been opened up, it is now perforated. A fine rubber catheter is guided into the upper angle of the ventricle, and is gently pushed onwards. The obstruction may be of such a fragile nature that there is little real resistance, and the catheter passes into the dilated third ventricle. This is signalized by a gush of cerebrospinal fluid. If the obstruction is more definite and cannot be overcome by the catheter, a millimetre probe is used to open up the closed communication (*Fig.* 149); this instrument, however, must be used with extreme care, as any forcible manœuvre may very easily result in perforation of the brain tissue around.

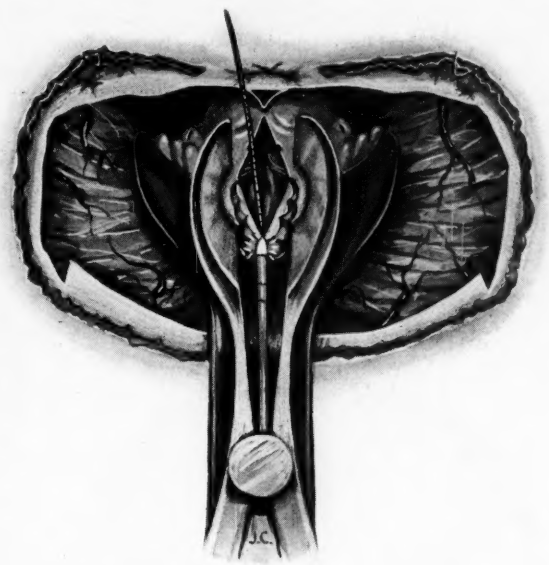

FIG. 149.—*The suboccipital operation*: 6.—Final step to relieve an obstruction in the aqueduct. The roof of the fourth ventricle has been opened and the lower part of the vermis split. With the aid of the nasal speculum the upper terminus of the fourth ventricle is exposed. A graduated probe is inserted through the aqueduct into the third ventricle.

After the channel has been opened with the probe the small rubber catheter is inserted, and it is demonstrated by the free escape of cerebrospinal fluid that the communication has been established.

As regards the further proecdure, Dandy recommends that the rubber catheter should be left *in situ* for several weeks, the lower end, cut short, being coiled up in the cisterna magna. He believes that this permits the formation of an epithelial lining around the tube, and diminishes the possibility of secondary closure. At first we followed this advice, but in the later series of cases we have been satisfied with efficient canalization of the iter, and it would seem that the restoration of the flow of the cerebrospinal fluid is sufficient to keep the channel open.

The Closure of the Wound.—If the operation is to be a successful one, the relief of the obstruction must be followed by the most careful closure of the wound. A leak of cerebrospinal fluid to the surface is unlikely to become spontaneously arrested, and it ends almost certainly in sepsis and death.

An attempt should be made to bring the dural edges together with a continuous catgut suture; the relief of tension which has resulted generally makes this procedure possible. The muscles are then closed in two layers, and the advantage of the straight incision over the crossbow incision now becomes evident, because the closure can be accomplished so much more efficiently.

In the immediate post-operative period attention must be paid in case the intracranial tension increases to such an extent as to lead to a leakage of fluid. If the tension is becoming marked, ventricular puncture should be practised, and if necessary repeated.

THE TREATMENT OF EXTRAVENTRICULAR HYDROCEPHALUS.

In this type of the disease the problem is in some respects more difficult than in the case of the ventricular variety. The obstruction is a widespread adhesive one at the base of the brain, and it is therefore inaccesible to direct removal. It has to be borne in mind, however, that certain cases of the extraventricular variety show a spontaneous arrest of the disease, a possibility which can never be hoped for in the intraventricular variety.

At the present time the attempts at treatment have been directed towards diminishing

the production of the cerebrospinal fluid to such an extent as to bring it within the power of absorption which exists, for of course a certain degree of absorption still continues. There are two methods which have been used in securing this diminished production of cerebrospinal fluid.

Dandy[14] has advised the removal of the choroid plexus from within the lateral ventricle, and he has published successful results in several cases. We have hitherto been content with less drastic measures. Intraventricular plexectomy is an exceedingly grave operation to perform, and there is no physiological proof that removal of a limited amount of choroid plexus proportionately diminishes the production of the cerebrospinal fluid. Stiles suggested the possibility of diminishing the production of the fluid by ligation of the common carotids, and in 1898[15] and again in 1912[16] he reported favourable results from this operation. It is clear, of course, that it is only the extraventricular type which will benefit from this procedure ; its employment in the ventricular variety will inevitably lead to disappointment, and this may to some extent explain the adverse criticism which the method has received.

We have treated all the examples of extraventricular hydrocephalus which have come under our care by ligature of the common carotids, and the results have been sufficiently promising to warrant the continuation of this method. The actual results are communicated later. The technique of the operation requires no detailed description—the vessels are tied at the crossing of the omohyoid muscle at an interval of ten days.

FIG. 150.—Suggested operation for the relief of certain types of extraventricular hydrocephalus. The pathway of the cerebrospinal fluid to the absorbing area of the cerebral subarachnoid space has been obstructed by adhesions between the free edge of the tentorium and the adjacent brain. By entering the skull above the lateral sinus and elevating the occipital lobe an opening has been cut in the tentorium outside the adherent area. The arrow indicates the new pathway for the cerebrospinal fluid.

We confess that it seems unreal that ligature of the common carotid vessels should result in a diminished production of cerebrospinal fluid, as, through the medium of the anterior choroidal vessels, they are responsible for only a portion of the blood-supply of the choroid plexus. Nevertheless, we have definite clinical evidence that, following the procedure of ligation, a certain proportion of cases of extraventricular hydrocephalus become arrested. The procedure is such a simple one that it seems worth a more extended trial in the special type of case for which it is suited.

But the methods of plexectomy and carotid ligature are at best unsatisfactory. No definite result can be guaranteed, because they do not deal with the pathological condition which is responsible for the hydrocephalus, the subarachnoid obstruction. Considering the problem from the etiological point of view, the obvious remedy is to open up a new pathway for the fluid in order to permit it to pass over the absorption area of the cerebral lobes. If the adhesions exist at the base of the brain, occluding the cisterns, it is difficult to see how any direct relief can be carried out ; but if the adhesions occur between the free edge of the tentorium and the mid-brain, there are greater possibilities of operative interference. In the cadaver we have been able to carry out a procedure which we hope after further trial to employ in a certain variety of extraventricular hydrocephalus, the variety which is shown by ventriculography to be the result of adhesions between the mid-brain and the free edge of the tentorium. The proposed procedure is illustrated diagramatically in the accompanying sketch (*Fig.* 150). The skull is trephined immediately above the lateral sinus, midway between the

mastoid process and the external occipital protuberance. The dura is opened, and the occipital lobe is elevated; the upper surface of the tentorium is exposed, and this is carefully divided radially without damage to the lateral sinus: the incision through the tentorium is prolonged inwards as far as is safely possible. Through the incision thus made it is conceivable that a fresh channel may be established for the circulation of the fluid. The procedure is still hypothetical as far as its practical value is concerned, but it offers possibilities which we hope to test.

RESULTS.

Tables 3 and 4 summarize the cases and the results obtained. Two cases of hydrocephalus associated with tumours are not included in this summary.

Table 3.—VENTRICULAR TYPE.

NO.	NAME AND AGE	DEGREE	RESULT
1	J. S., 6½ months	4th	Died
2	E. A., 4½ months	3rd	Died
3	E. H., 9 weeks	4th	No operation
4	A. Y., 10 months	4th	Died
5	M. D., 5 months	3rd	No operation
6	R. M., 3 months	4th	Died
7	C. F., 7 months	4th	Cure
8	D. T., 7 months	4th (specific type)	Improved
9	N. S., 3 months	4th	No operation (died)
10	T. C., 1 year 4 months	3rd	Died
11	M. M., 4 months	4th	Arrested (probable cure)
12	M. C., 3 years	3rd	Improved
13	J. H., 6 months	3rd	Cure

Analysis of the Results of the Ventricular Type.—At first sight the results appear to be exceedingly unpromising—out of 13 cases, in 3 the condition was so advanced as to preclude any prospect of success from operative interference, 5 cases succumbed from the operation, in 3 cases the operative interference has resulted in apparent arrest of the disease, but we do not classify these as cures, because there has been no diminution in the bulk of the head, and the mental condition has remained permanently impaired; it is unlikely that these children will ever become useful members of society, capable of taking their share in the work of the world. In 2 instances (and this is the hopeful side of the problem) it would appear that we have been successful in effecting a complete cure. The following is a brief epitome of the histories of these cases:—

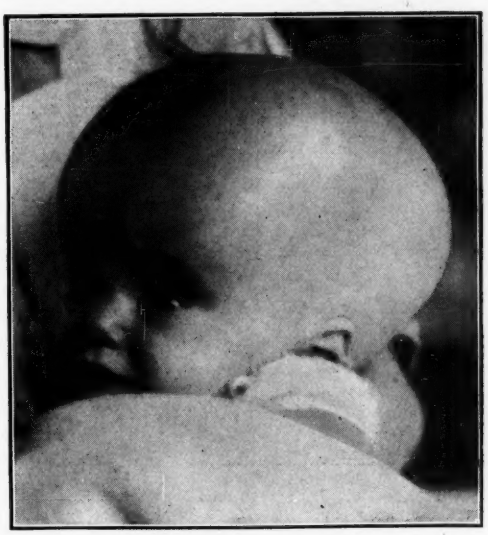

FIG. 151.—Case of hydrocephalus, C. F. Appearance of child before operation. The hydrocephalus was a ventricular one of the fourth degree.

Case 1.—C. F., 7 months. Female. Recommended by Dr. Brander, Fort William. On admission to hospital the child (*Fig.* 151) was suffering from a marked hydrocephalus; the fronto-occipital circumference was 20½ inches. The size and weight of the head was so great that it continually fell forward on the chest. Investigation showed that the hydrocephalus was ventricular, and of the fourth degree. The child was operated on in May, 1921, and, as a matter of fact, it was one of the cases done during the afternoon demonstration at the Children's Hospital when the British Association of Surgeons met in Edinburgh. An obstruction was found in the roof of the fourth ventricle, and this was relieved. An excellent post-operative recovery was made.

One year has now elapsed since the operation, and the accompanying photograph (*Fig.* 152) bears witness to the child's present condition. The head has shrunk in size, the fontanelles are closed, and the sutures well ossified; the general intelligence of the child is unimpaired; it stands without assistance, and it is beginning to walk. The only evidence of defect which remains is an internal strabismus present in both eyes (*Fig.* 153).

FIG. 152.—Case of hydrocephalus, C. F. Appearance of child one year after operation. An obstruction in the roof of the fourth ventricle was removed.

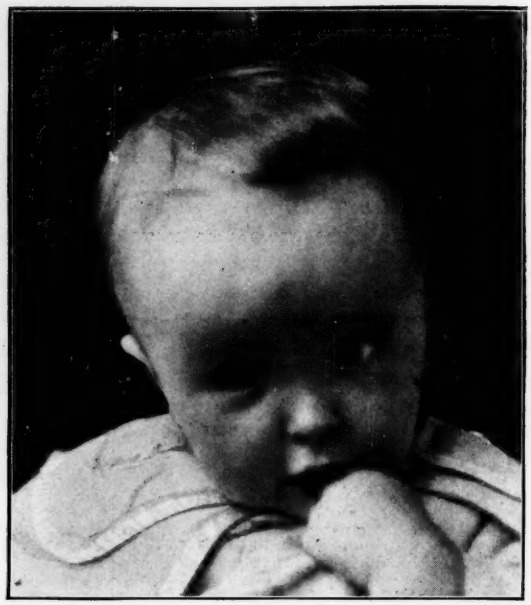

FIG. 153.—C. F. Operated on for a ventricular hydrocephalus of the fourth degree when 7 months old. Present appearance of the child.

Case 2.—J. H., 6 months. Male (Dr. Ainslie, Edinburgh). The child, on admission to hospital, was found to be the victim of a ventricular hydrocephalus of the third degree. It was operated on in October, 1921, and the obstruction in the iter was relieved. A good recovery was made.

Nearly seven months have now elapsed since the operation was performed, and a complete recovery appears to have been made. The head has diminished in size, and ossification is apparently complete except at the anterior fontanelle. The child is a sharp intelligent baby, and present appearances indicate normal development (*Fig.* 154).

FIG. 154.—J. H., age 12 months. Seven months after operation for a ventricular hydrocephalus due to an iter destruction.

This proportion of cases (2 out of 13) is, of course, exceedingly small, but there are indications which promise better in the future. The operative procedure is of a highly technical character, and considerable experience is necessary if certain errors are to be avoided. Evidence of this is brought out by the fact that of the last 7 cases only 1 has succumbed after operation, 2 have been cured, 3 have been improved in so far as the condition has apparently been arrested, while one case was so extensive as to permit of no operative interference. We hope that in the future the knowledge we have gained may still further improve the results.

An Analysis of the Results of the Extraventricular Type.—In this group there were 6 cases: only 5 were submitted to operative interference (ligature of carotids), one succumbing on admission to hospital. Of the remaining 5 cases, 1 succumbed within forty-eight hours of the first operation, as the result of hyperpyrexia, and 4 were successfully operated on. Of these, 3 have very definitely improved, and we believe that the hydrocephalus is now

arrested ; in the fourth case no improvement followed the operation, and the hydrocephalus increased to a fatal issue.

Table 4.—Extraventricular Type.

Name and Age	Method Adopted	Result
R. W., 4 months	Ligature of carotids	Condition arrested
S. S., 8½ months	„ „	Condition arrested
M. M., 1 year 2 months	„ „	Condition progressed (fatal in six months)
E. S., 9 months	No operation	Succumbed on admission
N. M., 9 months	Ligature of carotids	Condition arrested
A. P., 10 months	Ligature of one carotid	Succumbed to hyperpyrexia within 24 hours of operation

Out of a total of 4 cases of extraventricular hydrocephalus with carotid ligature, 3 have very definitely benefited (*Figs.* 155 and 156), and, though we do not wish at this stage to classify them as complete cures, we believe that everything points to a successful issue. The total series is, of course, too small to afford conclusive evidence, but the proportion of 3 improvements out of 4 cases has so encouraged us that we intend to continue to practise this method of carotid ligature in cases of extraventricular (communicating) hydrocephalus in preference to the method of plexectomy.

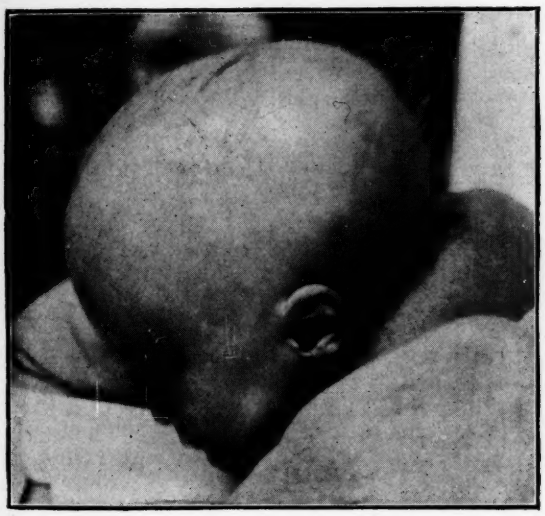

Fig. 155.—S. S., age 8 months. An example of an extraventricular hydrocephalus. Before operation.

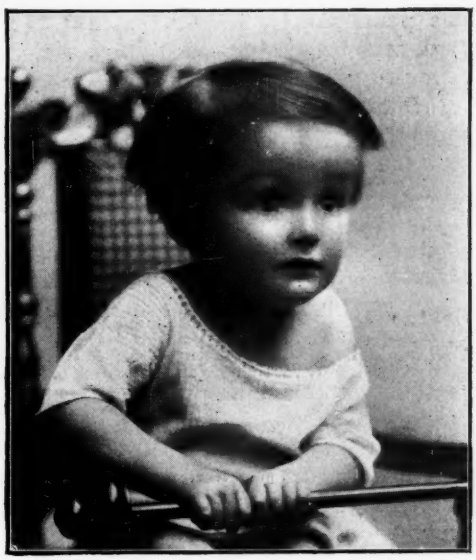

Fig. 156.—S. S. Extraventricular hydrocephalus. The same child as shown in *Fig.* 155, six months after ligature of carotids.

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A CLINICAL STUDY OF PHRENIC SHOULDER-PAIN; WITH SPECIAL BEARING ON THE DIAGNOSIS OF ACUTE ABDOMINAL DISEASE.

By ZACHARY COPE, London.

The purpose of this study is to show the great importance, in the diagnosis of acute abdominal disease, of pain referred to the shoulder from the diaphragm and the adjacent parts supplied by the phrenic nerve. The occurrence of pain on the top of the shoulder in disease of the chest and upper part of the abdomen has been known for many years. Early knowledge on the subject has been well summarized by Kidd.[1] A rational explanation of the symptom was first given in 1890 by Ferguson,[2] who showed that the phrenic nerve contained many afferent fibres. A very full clinical account of the symptom was published by Oelcker[3] in 1914. The writer's observations began before Oelcker's work was brought to his notice, and it is thought that the conclusions reached extend beyond those published by the Continental observer.

Definition.—By phrenic shoulder-pain is indicated pain felt on the top of the shoulder in consequence of an irritation of the terminations of the phrenic nerve. For the purpose of this study, only the occurrence of the pain consequent on the irritation of phrenic fibres in or adjacent to the diaphragm will be considered.

The referred pain caused by such irritation is felt over the areas of skin supplied by the same spinal segments which give origin to the phrenic nerve. The sensory distribution areas of the third, fourth, and fifth cervical segments are the parts involved, though of these the fourth segment is by far the most important. Roughly speaking, the pain is felt within the areas supplied by the descending cutaneous branches of the third and fourth cervical nerves. Sometimes the pain will be described as shooting down the outer aspect of the arm in the distribution area of the fifth cervical segment.

It is very necessary to distinguish this pain from that infrascapular segmental pain commonly felt in gall-stone disease and various gastric conditions. Such pain is often loosely and misleadingly referred to as pain in the shoulder region, but it has no connection with the phrenic pain we are considering.

We do not include in this account that pain which has been described by some authorities as being felt on pressure over the trunk of the phrenic nerve in the neck, for we are rather sceptical as to whether one can entirely exclude superficial tenderness in pressing over the phrenic nerve.

The illustrative cases mentioned in the text are very necessary to the argument, for each has been chosen to illustrate some particular point. Nature is constantly making experiments on human beings, and by noting carefully the conditions existing in any experiment one may draw conclusions which have the force of scientific trial.

The Nature of the Pain.—Phrenic shoulder-pain varies considerably in intensity and quality. Usually it has the qualities of an ache, and is regarded by the patient (and often by the doctor) as a rheumatic pain. Sometimes it is very sharp and stabbing, or it may feel as if a nail were being driven in at the painful spot. Very frequently the discomfort occasioned may not be severe enough for the patient to complain, so that it is necessary to inquire about the pain in every case if one is to avoid missing the symptom. Some patients say that they have no pain, but that there is a sensation of stiffness in the affected part.

Diseases in which Phrenic Shoulder-pain may occur.—Any condition which may cause irritation of the diaphragm or the serous coverings of the diaphragm, or the contiguous tissues supplied by the phrenic nerve, may be the cause of phrenic shoulder-pain. It is clear, therefore, that diseases of the liver, stomach, duodenum, pancreas, and spleen below the midriff, and the pleura and pericardium above that muscle, will most commonly cause the pain. Inflammatory disease of the lower abdomen will only demonstrate the symptom if the inflammatory process reaches to the diaphragm. Sudden intraperitoneal hæmorrhage may, by pressing up under the diaphragm, irritate it sufficiently to cause shoulder-pain.

I have known the pain of diagnostic value in the following conditions :—

Liver abscess
Perforated gastric and perforated duodenal ulcer
Subphrenic abscess
Cholecystitis with adjacent peritonitis
Perforation of the gall-bladder
Splenic infarct
Spontaneous rupture of the spleen
Acute pancreatitis
Appendicitis
Ruptured ectopic gestation
Dilated stomach
Actinomycosis of the thoracodiaphragmatic junction
Diaphragmatic pleurisy
Basal pulmonary infarct
Pericarditis

Hepatic Abscess.—Perhaps in this condition more than in any other it is general knowledge that pain at the tip of or on the top of the shoulder may occur. It was in connection with liver abscess that my interest was first aroused in the subject of phrenic shoulder-pain whilst abroad during the war, and after a careful study of the pathological data furnished in the valuable monograph of E. J. Waring,[4] the conclusion was reached that shoulder-pain accompanying liver abscess was seldom or never felt unless the pus was near to or threatening to perforate the diaphragm. This conclusion has been confirmed by clinical experience, so that one may state with confidence that in any patient with symptoms of liver abscess who has phrenic shoulder-pain the abscess must be close to and irritating the diaphragm. It is unnecessary to give examples of this condition ; but it is important to remember that the shoulder-pain may be the only symptom calling attention to such an abscess.

Perforated Gastric and Duodenal Ulcer.—Phrenic shoulder-pain is a very important symptom in the case of a perforated ulcer. Though not invariably present, it is sufficiently constant to make it a necessity for the careful surgeon to inquire concerning the symptom in every acute abdominal case. It is necessary to inquire, since the shoulder-pain is usually overshadowed by the abdominal pain, and no spontaneous complaint may be made. Sometimes the referred pain comes on simultaneously with the abdominal, but occasionally it is delayed in onset. In the first case of perforated ulcer in which I noted shoulder-pain, it was only when the patient lay down in bed that the pain drew forth complaint.

With the perforation of a duodenal or pyloric ulcer the pain is usually felt in the right supraspinous fossa or over the right acromion process. Less commonly the pain is felt just above the right clavicle. With an anterior perforation of the stomach the pain is referred to the region of the left clavicle or left acromion process. If the perforation be near the cardia, and the escaping contents irritate the median portion of the diaphragm, pain may be felt over both acromioclavicular regions. I have known a patient complain also of a sense of weakness in the upper arm in addition to the shoulder-pain. It is not unlikely that this may have indicated that the sensory fibres of some of the arm muscles were reflexly affected.

Subphrenic Abscess.—Phrenic shoulder-pain is present at some time or other in the evolution of nearly every subphrenic abscess, though, curiously enough, I have been unable to find any record of this very helpful symptom in any of the classical articles on the subject. The pain is generally felt only in the stage of active formation of the abscess. When once the abscess is localized no complaint of shoulder-pain may be made. The position of the referred pain varies according to the position of the abscess (*see below*).

Gall-bladder Conditions.—Any inflammatory condition spreading from the gall-bladder may cause phrenic shoulder-pain. Acute cholecystitis does not cause it until the inflammation has spread beyond the confines of the viscus. The passing of a stone down the biliary ducts is not accompanied by top-of-the-shoulder pain unless there is accompanying inflammation round the ducts. Rupture of an infected gall-bladder may cause the significant pain. In gall-bladder conditions the pain is generally referred to the right supraspinous fossa, occasionally to the acromiodeltoid region.

Splenic Conditions.—Slow enlargements of the spleen do not lead to diaphragmatic irritation and its characteristic pain, but the local peritonitis consequent on a splenic infarct, and the irritation caused by collecting blood-clot, are sufficient to produce the symptom.

Case 1.—**Phrenic shoulder-pain consequent on spontaneous rupture of the spleen.**

On April 6, 1922, a young man was admitted to the Bolingbroke Hospital with the following history. He had returned from active service in India on account of malaria, for which he had been recently treated. At 3 a.m. on the day of admission he had awakened with acute left-sided abdominal pain. Two hours later he felt pain all over the top of the left shoulder. On admission at 3 p.m., he was collapsed and anæmic, had a tender tumid abdomen, and there were signs of free fluid in the abdomen. The diagnosis of spontaneous rupture of the spleen (which had been brilliantly made by his private doctor) was considered certain in view of the shoulder-pain. Operation revealed much free blood in the peritoneal cavity and a collection of clotted blood forming a cast of the under surface of the left dome of the diaphragm. Splenectomy was performed and an excellent recovery followed. The splenic rupture from which the bleeding had occurred was not large.

Case 2.—**Infarct of spleen.**

M. L., female, admitted to St. Mary's Hospital, Aug. 26, 1920, was found to be suffering from ulcerative endocarditis. She complained of pain over the left acromioclavicular joint. At the autopsy, Sept. 8, 1920, there was found an infarct of the central zone of the spleen and a small infarct of the upper pole.

Acute Pancreatitis.—I have not myself seen a sufficient number of cases of acute pancreatitis to be able to dogmatize or generalize on its symptomatology; but in rarer diseases it is permitted to collate experiences outside one's personal practice. On *a priori* grounds I had long thought that acute pancreatitis should, by irritation of the left crus of the diaphragm, lead to phrenic shoulder-pain; but until recently, the cases I questioned never gave an affirmative answer to the inquiries concerning the pain. Just recently a case I saw at St. James's Hospital presented the symptom. She was a woman, age 46, upon whom Dr. MacCormac operated successfully for a very acute pancreatitis. On questioning her she was very emphatic that at the onset of the agonizing abdominal pain she also had pain in the left supraspinous fossa, which was relieved when the abdominal pain was relieved.

For an even better illustration of shoulder-pain in acute pancreatitis, I am indebted to the kindness of Mr. Tudor Edwards. I give the account in his own words.

Case 3.—**Acute pancreatitis.**

"The patient was a rather fat woman, age about 60, with a previous history of undefined gastric disturbance. She was somewhat distended, and had general abdominal tenderness, more marked in the left epigastrium. She was complaining of severe abdominal pain, and especially pain about the left shoulder. To the best of my recollection the pain appeared to be localized over the left supraspinous fossa. A rather interesting fact struck me at the time, namely, pressure over the abdomen over the pancreas increased the shoulder-pain. At operation she had the usual signs of acute pancreatitis, brown effusion, fat necrosis, and a large distended pancreatic swelling, with gall-stones. Cholecystostomy, with drainage of the pancreas anteriorly, was done, and eventually complete recovery took place. Incidentally, there was no post-operative complaint of shoulder pain."

It is unnecessary to comment on Mr. Tudor Edwards' excellent description.

Acute Appendicitis.—It is seldom that phrenic shoulder-pain is a symptom in appendicitis, for the very good reason that it is infrequent for the infection to extend up to the diaphragm.

With a long ascending appendix, however, or in cases where the cæcum and appendix are much higher than normal, the symptom is to be expected. I can only find references to two or three such cases in Continental literature, and I have myself only known of two cases in which such shoulder-pain occurred.

Case 4.—**Perforation of a retrocæcal appendix.**

R. M. was taken with acute abdominal pain, followed about fifteen hours later by severe pain over the right acromial region. A perforated retrocæcal appendix was found at operation, and there was a great amount of seropurulent fluid in the abdominal cavity. For three weeks after the operation slight pain continued to be felt in the right shoulder on deep inspiration. The initial pain in this case was described as that of a nail being driven into the acromioclavicular joint.

It is specially to be noted in this case that the pain was not felt on top of the shoulder until some hours after the abdominal pain. This was also exemplified in the second case, in which pain was felt over the right clavicle twelve hours after the onset of the abdominal pain. At operation an inflamed ascending appendix with spreading peritonitis was found, and some lymph was noted in front of the liver.

Ruptured Ectopic Gestation.—The interesting fact has long been known that in some cases of ruptured ectopic gestation pain may be felt over the clavicle. If the question be put as a routine it will be found occasionally that pain is complained of in the supra-spinous fossa and over the acromioclavicular joint and deltoid. This pain is clearly due to sudden irritation of the diaphragm by the blood which pours from the pregnant tube.

Case 5.—**Tubal mole.**

A. R., age 30, who had not missed a period but whose last monthly loss had been much under normal, was seized with acute abdominal pain and vomiting on Dec. 23, 1920. At the same time she had pain over both clavicles. Her condition improved for a day, but was worse on Dec. 25, when she fainted and had a rigor. On Jan. 2, 1921, she was admitted to the Bolingbroke Hospital, where I removed a right tubal mole. There was much blood-clot in the pelvis.

The clavicular pain was only felt with the first severe hæmorrhage, when it may be surmised the blood flooded the anterior subdiaphragmatic region.

Actinomycosis of the Thoracodiaphragmatic Junction.—When actinomycosis attacks the chest it is almost always at the base, and the diaphragm is usually attacked early. Though a slow inflammatory process, the condition may cause sufficient irritation to produce the characteristic shoulder-pain. The pain may seriously mislead, and on the right side may give rise to a mistaken diagnosis of gall-stones, as in the following instance.

Case 6.—**Actinomycosis mistaken for gall-stones.**

A man came under my care on Dec. 1, 1913, for abdominal pain. He had been well until three weeks prior to that date. He had at that time been taken with very severe pain on top of the right shoulder and in the right hypochondrium. The pain had lasted, with occasional intermissions, for the three weeks. There was no jaundice, but some tenderness and rigidity in the right hypochondrium. He was admitted to hospital, where a physician colleague diagnosed duodenal ulcer or possibly subphrenic abscess. My own opinion, based on the shoulder-pain (the correct significance of which I did not at that time understand), inclined to gall-stones. Operation revealed a rather large liver and distended gall-bladder, but no sign of gall-stones or other disease. I drained the gall-bladder. He was not much relieved. A month later he developed a cough, and a large fluctuating swelling was noted in the right loin. This was opened and from it were obtained characteristic actinomycotic granules. The diagnosis was confirmed microscopically.

Since this case I have had another patient with actinomycosis involving the left thoracodiaphragmatic junction, who had pain in the left supraspinous fossa, and the local and referred pain diminished and increased together.

It is not within the province of this study to discuss phrenic shoulder-pain of thoracic origin save in the section on localization-value of the pain.

The Localizing Value of Phrenic Shoulder-pain.—Clinical evidence supports the view that the position of the referred pain on the top of the shoulder varies according to the part of the diaphragm irritated. This conclusion is at variance with that reached by Capps[5] as the result of his experimental irritation of the diaphragm in cases of pleural effusion. He states that " the maximum pain-point in the neck in a given individual was

the same from whatever part of the diaphragm it was elicited". It is possible that the different results may be due to the difference between a mechanical stimulus and that due to inflammatory conditions.

It is necessary, therefore, to put on record the evidence which points to the view that there is a correspondence between the part of the diaphragm affected and the region of the shoulder over which pain is referred. It is agreed by all observers that irritation of the right side of the diaphragm causes pain on the right shoulder, whilst left shoulder-pain results from some affection of the left portion of the diaphragm. This is a general rule to which I have seen but one—and that a doubtful—exception. The localization which has apparently been overlooked by other observers and which is at variance with Capps' conclusion may be summarized as follows. Irritation of the anterior part of the diaphragm causes pain in the corresponding clavicular or supraclavicular regions; irritation of the posterior part of the diaphragm causes pain in the supraspinous fossa of the same side; irritation of the top of the phrenic dome causes pain in the corresponding acromio-clavicular regions; and finally, pain felt over both shoulders indicates a median diaphragmatic irritation.

Evidence that Irritation of the Anterior part of the Diaphragm causes Pain in the Anterior part of the corresponding Shoulder Region.

Case 7.—**Subphrenic abscess.**

In September, 1920, a youth was admitted to the Bolingbroke Hospital with symptoms of general peritonitis. He was so ill that the resident surgeon who operated thought it wise merely to drain the pelvis. The general condition thereafter improved, and the fever abated. Ten days later he complained of the occasional occurrence of pain exactly over and along the left clavicle. The medical officer (Major Lowe) examined the left lung base, discovered signs of pleurisy, and asked me to see the patient. Examination showed dullness, and diminished breath and vocal sounds at the left base posteriorly. The presence of fluid did not account for the clavicular pain; but on listening to the front of the left chest at the level of the diaphragm pleuritic respiratory crepitations were easily detected. The history of the case, combined with the irregular fever and clavicular pain, pointed to the presence of a subphrenic abscess in the left anterior region. Sub-pleural resection of the anterior part of the left 10th rib was performed, and a subphrenic abscess, which occupied a situation just in front of the spleen, opened and drained.

Case 8.—**Diaphragmatic pleurisy.**

In August, 1920, I saw a patient with acute pain in the right side of the abdomen suggesting an intra-abdominal lesion. The illness began with an acute stabbing pain in the right sub-clavicular fossa. Examination revealed nothing abnormal in the abdomen, but below the right clavicle was a hyperalgesic area, and on auscultation of the chest a soft, sticky pleural crepitation could be heard at the lowest level of the right pleura in front. No adventitious sound and no dullness could be found posteriorly. The temperature was 103°. A diagnosis of diaphragmatic pleurisy was confirmed by the after-course of the disease. Slight basic pneumonia developed, but a good recovery ensued.

Case 9.—**Pulmonary embolism due to malignant disease.**

A woman with rapidly-growing malignant intra-abdominal growth was taken with sudden acute pain under the right breast accompanied by pain in front of the right shoulder and the lower anterior part of the neck. The right arm also felt weak. The attack was accompanied by breathlessness, and a pulse of 140. Both pains had disappeared when I saw her ten days after the attack. There could be little doubt that the attack was due to a pulmonary embolus with anterior diaphragmatic irritation.

Perhaps the most instructive case that I have met with showing the value of phrenic shoulder-pain is the following:

Case 10.—**Perforated ulcer near the cardia, coupled with a subphrenic abscess.**

In 1920, a young woman was admitted to the Bolingbroke Hospital with a history that five hours previously she had awakened with terrible pain in her abdomen and severe pain in both shoulders. When I saw her soon after admission she presented the signs and symptoms of a perforated gastric ulcer. She stated that the pain on the shoulders was almost as severe as that in the abdomen. Asked to localize the shoulder-pain she pointed to the site of the acromio-clavicular joint on each side. When I gently touched the spots indicated she cried out with pain. I concluded the median part of the diaphragm was irritated by a perforated ulcer near the cardia, and this was confirmed in opening the abdomen.

The ulcer-perforation was sewn up, and when I saw her again six hours after the operation the shoulder-pain had disappeared. Five days after the operation pain was again felt over the left acromioclavicular joint. Two days later there was a little fever, and on the tenth day after operation dullness was detected at the left lung-base, posteriorly. Concluding that there was a left subphrenic abscess I resected a part of the left 10th rib. Finding that the pleura came down almost to the costal margin, I made a second incision at the costal margin anteriorly, passed my finger up, lateral to and in front of the splenic flexure of the colon, and opened a large stinking left anterior subphrenic abscess. A large rubber drainage tube was inserted. After the opening of the abscess the acromial pain disappeared, but pain was complained of all along the left clavicle. Thus, when the irritation was removed from the left dome of the diaphragm and the anterior portion of the muscle was irritated by the rubber tube and pus, the pain was transferred to the clavicular region.

If this view of the localization of the referred pain be accepted, it provides a ready explanation for the symptom of pain over the clavicles noted in some cases of ruptured ectopic gestation, and mentioned by de Quervain in his excellent book. The blood poured into the peritoneal cavity most readily ascends in front of the intestine and would impinge upon and irritate the anterior part of the diaphragm. It is necessary to state, however, that in cases of extra-uterine pregnancy which rupture it is not uncommon for the patient to have pain in the supraspinous fossa of one or other side—a fact easily explained by the collection of clot against the posterior part of the diaphragm.

Evidence that Irritation of the Posterior part of the Diaphragm (and the adjacent parts supplied by the Phrenic) leads to Pain in the Suprascapular Region.

In the first place liver abscesses, which in the majority of cases occupy the posterior and upper part of the right lobe of the liver, most commonly cause pain in the right suprascapular region. A fact so well known does not call for illustrative cases, but anyone who desires confirmation of the statement has but to study carefully the excellent pathological data of E. J. Waring.[1] Secondly, in cases of perforated pyloric ulcer causing immediate irritation in the region of the right crus and the subhepatic area of the diaphragm, the pain is usually felt in the posterior part of the right shoulder region. Thirdly, in those few cases of pancreatitis which are accompanied by shoulder-pain, such pain is referred to the left suprascapular region.

It is sometimes possible in clinical work to obtain a direct stimulation of one particular region, thereby confirming or confuting an opinion, as in the following instance :—

Case 11.—**Phrenic irritation caused by drainage tube.**

A patient under the care of a colleague underwent cholecystectomy, at the end of which operation a rubber tube was inserted down to the stump of the cystic duct. After the operation the patient complained of very severe pain in the right supraspinous fossa. The stitch fastening the tube to the skin was released and the tube withdrawn about an eighth of an inch. The suprascapular pain immediately ceased.

By consultation with anatomists I have carefully attempted to ascertain exactly where the undue pressure would have been made by a tube in the position indicated above, and the conclusion is that it was pressing against the peritoneum over the vena cava and the right crus at the posterior boundary of the foramen of Winslow. That this is no isolated case may be judged by the following case related to me by Mr. Eric Pearce Gould :—

Case 12.—**Another case of irritation by drainage tube.**

Miss E. Operation, Feb. 7, 1920. Cholecystectomy was performed. When seen one hour after, she was complaining of severe pain of a gripping character in the right supraspinous fossa. Her binder was loosened and she dozed ; on waking the pain was gone and she had forgotten all about it.

Here again the lessening of pressure causes the cessation of the pain, and in each case the pressure of the tube against the right crus and vena cava caused pain in the corresponding supraspinous fossa.

The above case-illustrations afford strong presumptive evidence, if not proof, that there is a correspondence between the part of the diaphragm irritated and the position in which the referred pain is felt on the shoulder.

Is there any Means of Distinguishing the Phrenic Shoulder-pain caused by Thoracic Disease from that caused by Abdominal Disease?

It may be stated at once that there is no certain way of distinguishing the source of the pain, but it is sometimes possible to gain assistance of value by noting the exact position of the pain.

There can be little doubt that acute pleural pain is due to friction between the opposing pleural surfaces. Diaphragmatic friction is naturally most common in the region of the costodiaphragmatic sulcus. In a person who is the subject of acute disease the recumbent position is usually assumed, and any pleural effusion gravitates to the posterior costodiaphragmatic sulcus. Friction is therefore not so likely to persist in the posterior sulcus. In cases with slight effusion, friction in the anterior costodiaphragmatic sulcus may not be interfered with by the fluid poured out. It is likely therefore that in a series of cases of diaphragmatic pleurisy there will be a larger proportion of patients who have pain referred from the extreme anterior part of the diaphragm. From this region pain is referred to the corresponding clavicular and subclavicular regions. It is a clinical fact that acute subclavicular pain of phrenic origin is more commonly of thoracic than of abdominal origin. On the right side such subclavicular pain is usually of thoracic origin (*see Case* 8). On the left side subclavicular pain may also be caused by perforation of an ulcer on the anterior wall of the stomach near the cardia.

When the pericardial portion of the diaphragm is affected the pain is either just above, over, or below the left clavicle.

Case 13.—**Phrenic shoulder-pain due to pericarditis.**

W. M., age 20, was admitted to St. Mary's Hospital on March 19, 1921. It was elicited that on March 8 he had been taken with a sudden acute pain under the left collar-bone. The pain lasted half an hour. It came on again when he lay down at night, and seemed to catch him when he took a deep breath. It got worse until March 19, when the pain was continuous and did not alter with the position of the patient. There was also pain in the epigastrium and along the right costal margin. On admission he was cyanosed. On March 21, a faint pericardial rub was heard just outside the sternum in the 3rd left intercostal space. A few days after admission he still had a little pain in the left subclavicular region, and the left arm felt a little numb over the deltoid.

Phrenic Shoulder-pain in Gall-bladder Disease.—It has long been an accepted teaching that in biliary colic the pain may radiate to the top of the right shoulder. This dogma has been transmitted from one generation to another and from text-book to text-book without any discrimination between the varieties of biliary colic, and for the most part without any operative or post-mortem account of the condition which caused the referred pain. Observation of a consecutive series of abdominal cases with pain on the top of the right shoulder will easily demonstrate that :—

1. Gall-stones and gall-bladder disease are less commonly the cause of phrenic shoulder-pain than are perforated pyloric or duodenal ulcer.

2. Neither cholecystitis nor impaction of a stone in the cystic duct causes pain on the top of the right shoulder unless there is accompanying local peritonitis.

3. A stone impacted in the common duct does not cause pain on the top of the shoulder until congestion and œdema of the adjacent parts result.

The first of these three points might not hold good in the case of any particular surgeon ; but in the general series of cases which fall to the lot of the ordinary surgeon it is certainly true.

Regarding the second point, I put it on record that I have never yet seen a case of gall-stones exhibiting pain on the top of the right shoulder unless there has been accompanying local peritonitis, or congestion and œdema of the neighbouring parts.

Some confusion has arisen because many observers loosely and incorrectly speak of "pain in the shoulder" when they mean pain under the right scapula. Before any comparable data can be obtained it is necessary for the observer to state clearly and exactly where the pain was felt, and not to record merely "pain radiating to the shoulder or shoulder-blade."

I append representative cases of gall-bladder disease to show the kind of pathological change which does or does not give rise to the shoulder-pain.

Case 14.—**Stone in the cystic duct—no shoulder pain.**

Mrs. C., admitted to the Bolingbroke Hospital in October, 1920, with pain in the right hypochondrium and right infrascapular region. No pain on the top of shoulder. No abdominal rigidity. Tender gall-bladder easily palpated. At operation, a very distended gall-bladder filled with thick mucoid fluid was found, and a stone discovered blocking the cystic duct.

Here there was no local peritonitis and no phrenic pain.

Case 15.—**Gall-stones, acute cholecystitis, and commencing peritonitis, with pain on top of the shoulder.**

Mrs. C., age 68, who had had three attacks of pain in the right hypochondrium during the last few years, was taken ill five days before I saw her, in April, 1920, with pain in the right upper abdomen radiating to the right infrascapular region. When I saw her the temperature was 100° and, though there was no abdominal-wall rigidity, there was pain on pressing deeply over the gall-bladder. No pain had been felt at the top of the shoulder. She was moved to hospital in an ambulance, and the first thing she said to me when I saw her there was that on the journey she had felt pain all over the top of the right shoulder. Operation showed acute cholecystitis, omental adhesions, free fluid, and spreading peritonitis; one large gall-stone was found in the gall-bladder.

In this case my inference was that the examination and removal of the patient caused the extension of the inflammation to the tissues covering the diaphragm.

Case 16.—**Stone in the common duct. Pain in the top of the shoulder starting when the abdominal pain ceased.**

Mrs. M. T., age 35, admitted to the Bolingbroke Hospital in February, 1922, with a history of twenty-four hours' acute abdominal pain followed by jaundice. No pain in the back. When the jaundice began and the abdominal pain ceased she began to feel pain at the back of the neck (in the supraspinous fossa at the anterior border of the trapezius). Jaundice gradually became worse. On Feb. 24, I operated and removed a gall-stone from the supraduodenal part of the common bile-duct. The gall-bladder was full of stones, which were removed. This patient was quite certain that the shoulder-pain (which she thought was rheumatic) did not begin till the abdominal pain ceased and jaundice began. At the operation, the tissues round the foramen of Winslow were œdematous and inflamed, though the gall-bladder itself was not very inflamed.

In this case no phrenic shoulder-pain was felt whilst the abdominal pain, caused by the stone passing through the cystic duct, persisted, but so soon as it stuck in the common duct œdema and inflammatory reaction followed, and irritation of the neighbouring phrenic nerve-endings at the posterior margin of the foramen of Winslow caused the shoulder-pain.

In the days when the abdomen was not opened for gall-stones while the patient was alive, there was excuse for the view that pain on the top of the shoulder was caused by the passing of a stone. A phrenic twig to the liver or biliary ducts served as sufficient anatomical reason for the fact of such pain. In *Reynolds' System* it was stated that in biliary colic the pain sometimes radiated to the clavicles. In *Bristowe's System* it was asserted that the pain might radiate to the shoulder-tip. One of the best modern *Systems* is more indefinite in stating that "pain radiates over the abdomen and to the right scapula; but in some cases the pain radiates to the left shoulder". Biliary colic usually causes pain just below the inferior angle of the right scapula, but seldom causes it in the acromioclavicular region. In considering biliary colic and referred pain caused thereby, one must realize that pain similar to that caused by the passing of a stone can be caused by inflammatory conditions, and that the passing of a gall-stone along the ducts may in itself lead to contiguous inflammatory changes.

Kehr[6] states that "one thing can be confidently asserted. It is by no means necessary (for biliary colic) that a stone should stop up the duct, for an inflammation of the gall-bladder without stone, and a swelling of its ducts, can produce a pain indistinguishable from biliary-stone colic". He continues: "It would in my opinion be better if we abandoned the term stone-colic, for the stone as a foreign body causes generally no pain. I have found a stone stuck in the neck of the gall-bladder and in the duodenal papilla

without the patient having any pain. Why? Since inflammation was absent in each case".

In *Osler and McCrae's System of Medicine* an enlightened view is expressed: "In the great majority if not in all cases local examination (in gall-stone colic) reveals tenderness, abdominal rigidity, and the other local phenomena of acute cholecystitis". It is also stated that "gall-stones are absent in 15 per cent of patients who have colicky pains". The writer concludes that "gall-stone colic should be interpreted rather as evidence of acute cholecystitis or acute exacerbation of chronic cholecystitis".

Some years ago Mr. Mayo Robson[7] wrote an interesting note on three cases in which pain at the tip of the shoulder was a prominent symptom, and in none of which was it caused by gall-stones. All three were due to tumours growing at the upper end of the kidney. The explanation offered for the pain was that a small branch of the phrenic passes to the semilunar ganglia. In view of the necessary irritation of the tissues over the diaphragm by such tumours, that explanation is hardly needed.

The Value of Phrenic Shoulder-pain in Diagnosis and Differential Diagnosis.—It should be a routine question to ask every patient suffering from acute abdominal pain whether pain is also felt on the top of one or both shoulders. The exact site is best indicated by placing the hand gently over the acromioclavicular region whilst the question is put. There can then be no ambiguity as to the part meant by 'the shoulder'.

The absence of shoulder-pain is perhaps not of so much importance; but the presence of supraspinous, supra-acromial, or supra- or subclavicular pain is always of great value in diagnosis, as indicating an irritation of the diaphragm or its serous coverings.

Such pain is often a distinguishing point in differential diagnosis. The conditions between which it may help to distinguish may usefully be enumerated.

1. *Differential Diagnosis of Acute Appendicitis and Perforated Duodenal Ulcer.*—With a perforated duodenal ulcer it is the rule for the patient to feel pain in the right supraspinous fossa (or over the right acromioclavicular joint and deltoid) simultaneously with or soon after the pain in the abdomen. Rarely does the shoulder-pain delay its onset for a few hours. In appendicitis, on the other hand, pain on the top of the shoulder is very rare, and in the rare cases of its occurrence the pain is not felt for some hours after the onset of the pain in the abdomen. If phrenic shoulder-pain develops some days after an acute attack of appendicitis, one must examine carefully for subphrenic abscess.

2. *Diagnosis between Perforated Gastric and Perforated Duodenal Ulcer.*—With a perforated pyloric or duodenal ulcer, the shoulder-pain is usually felt over the right supraspinous fossa, the right acromioclavicular joint, and deltoid; whilst a perforation of the anterior wall of the stomach causes either pain over both acromioclavicular regions (median irritation of diaphragm), or pain over or under the left clavicle (irritation of anterior part of left dome of diaphragm).

Case 17.—**Perforation of the anterior wall of the stomach.**

David B., age 49, admitted to St. Mary's Hospital, Nov. 19, 1921. He had been taken with acute abdominal pain at 9.30 a.m. the same day, and had also experienced slight pain under the left clavicle. There had been no pain in the right shoulder. General abdominal rigidity was present. The liver dullness was normal in the right axilla, but slightly diminished in front. From the presence of subclavicular pain I diagnosed a perforation of the anterior wall of the stomach, well to the left of the middle line. My colleague, Mr. Clayton-Greene, operated, and found a perforation in the position forecasted.

3. *Perforating Ulcer and Acute Pancreatitis.*—If the arguments as to the localizing value of phrenic shoulder-pain be accepted, it should follow that pain in the left supraspinous fossa accompanied by general abdominal symptoms of severity would most likely be due to acute pancreatitis. A posterior perforation of the stomach might cause such pain, but such a lesion would more likely cause adhesions and not be so acute in its onset. Any patient suffering from very acute abdominal symptoms in whom thoracic lesions can be excluded, may be reasonably supposed to be the subject of acute pancreatitis if pain

is simultaneously experienced in the left supraspinous fossa. It must be admitted, however, that this diagnostic help is only present in a minority of the cases.

4. *Right-sided Pleurisy and Abdominal Conditions.*—The right anterior part of the diaphragm is relatively seldom irritated by acute abdominal lesions, but pleurisy frequently attacks the corresponding superior surface of the muscle at the anterior costophrenic sulcus. If, therefore, a patient complains of abdominal pain and pain at the same time in the right subclavicular fossa, the most likely pathological lesion is right-sided diaphragmatic pleurisy.

5. *Ectopic Pregnancy and Perforated Gastric Ulcer.*—Sudden hypogastric pain associated with symptoms of collapse and accompanied by shoulder-pain in an adult woman should make one think of ectopic gestation. If the pain is felt over both clavicles or over the right clavicle, the diagnosis of ruptured ectopic pregnancy is almost certain.

CONCLUSIONS.

Pain of a referred nature is frequently felt on the top of the shoulder as a consequence of stimulation of the sensory terminals of the phrenic nerve in or near the diaphragm. The pain is felt in some part of the segmental areas corresponding to the 3rd and 4th, and sometimes even the 5th cervical segments of the spinal cord.

This referred pain is met with in many conditions which cause inflammation or irritation of the diaphragm or contiguous structures.

There is an important localizing correspondence between the part of the diaphragm irritated and the position of the referred pain on the shoulder.

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A preliminary note on " The Clinical Significance of Shoulder-pain in Lesions of the Upper Abdomen " was read by the writer at a meeting of the Clinical Section of the Royal Society of Medicine on Nov. 12, 1920, and published in the Proceedings in Feb., 1921.

ON SOLITARY FIBROMYXOMATA OF PERIPHERAL NERVE-TRUNKS, WITH A DESCRIPTION OF A CASE OF CYSTIC FIBROMYXOMA OF THE MEDIAN NERVE.

By ERIC A. LINELL, Manchester.

M. G., a woman, age 42, came to the out-patient department of the Ancoats Hospital in October, 1921, complaining of a lump in the right arm, which she had noticed growing gradually for four years, and more rapidly during the last month. When first noticed she stated it was the size of a hazel-nut.

Symptoms.—Patient's only complaint was that occasionally she had attacks of shooting pain from the site of the tumour down into the middle finger. She suffered no disability whatever, and had noticed no impairment either of muscular power or of sensation in the limb.

Examination.—This revealed a well-defined, painless, fusiform swelling on the antero-internal aspect of the upper arm slightly above the internal condyle of the humerus. The tumour was the size of a pigeon's egg, freely movable laterally, but not in the long axis of the limb. It was unattached to skin, and elastic to the touch, but fluctuation was not demonstrated. The essential connection of the tumour with the median nerve was not considered on account of the complete absence of motor or sensory symptoms. From the proximity of the tumour to the line of the nerve it seemed reasonable to ascribe the shooting pains in the median area to pressure, and a diagnosis was made of a soft fibroma arising from the deep fascia.

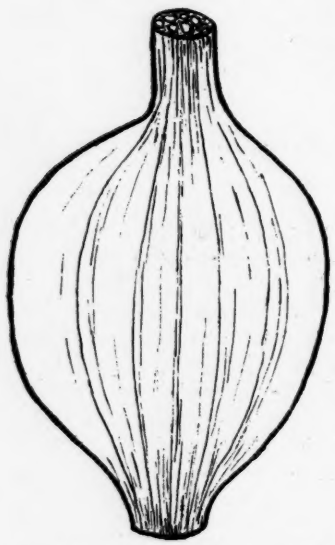

Fig. 157.—Naked-eye appearance of cyst after removal.

Operation.—This was performed on Nov. 21, 1921. Exposure of the tumour revealed a dark-blue fusiform swelling which appeared to interrupt completely the continuity of the median nerve. The swelling was definitely cystic, and incision allowed the escape of a considerable quantity of dark, fluid blood. As from naked-eye inspection it appeared impossible that there should be any nerve bundles connecting the proximal and distal portions of the trunk along the cyst wall, some doubt was thrown on the accuracy of the preliminary clinical examination. After careful consideration and in view of potential malignancy, the median nerve was resected half an inch above and half an inch below the tumour. This was removed, and primary end-to-end suture of the resected ends of the nerve was easily performed, assisted by flexion of the elbow. The tumour showed no adherence to surrounding tissues, and both resected ends appeared quite healthy. The skin incision was closed and the limb bandaged in full flexion at the elbow. Healing took place by first intention, and the patient was discharged from hospital on Dec. 8 with, of course, a typical median nerve paralysis.

A sketch of the specimen as removed at operation is reproduced in *Fig.* 157. After the specimen had been hardened in formalin, nerve-fibres were seen to be spread out in the wall of the cyst as shown in the sketch.

Subsequent Course.—The patient has been having massage and electrotherapeutic treatment since the operation. Professor Stopford examined her on March 17, 1922, nearly four months after the operation, and he considers that there are early signs of regeneration in view of a slight diminution in the area of lost protopathic sensibility and a positive Tinel's sign. There is no evidence yet of any motor recovery.

Histology.—In view of the extreme rarity of cystic tumours of nerves, it seemed worth while to make a detailed histological study of the specimen. The complete absence of

FIG. 158.—Section of cyst wall; low-power magnification; shows fibrous tissue with myxomatous areas. Note well-formed blood-vessels.

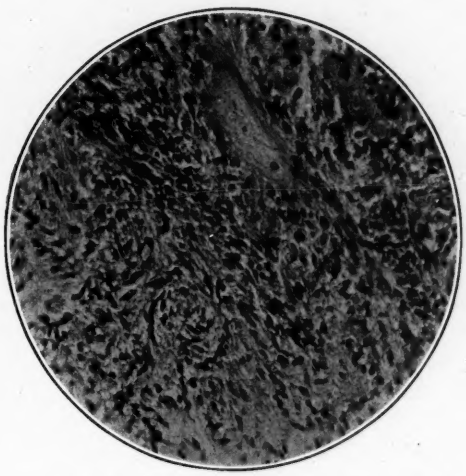

FIG. 159.—Wall of cyst; high-power magnification; shows the two main tissue elements of tumour.

motor and sensory symptoms in the case of a nerve tumour, which macroscopically gave no clear indication as to its nature, justified the histological investigation of the nerve above and below the lesion, both for signs of extension of the growth and of nerve-degeneration below the tumour.

Transverse sections of (1) the cyst wall; (2) the nerve above; and (3) the nerve below the tumour, have been stained with hæmalum and eosin, and in addition, transverse sections distal to the tumour have been stained by Weigert's method to show the condition of nerve-fibres distal to the lesion.

1. *The tumour*, as seen in a transverse section of the cyst wall, consists for the greater part of a very loose reticulum of branching cells with well-marked nuclei. Mitotic figures are not seen, and the blood-vessels throughout the section are well formed. Dr. Charles Powell-White considers that these cells bear a strong resemblance to the essential cell element of a glioma, but, as a glioma of a peripheral nerve is unknown, he thinks it more probable that they are young fibroma cells. Scattered throughout the section are definite areas of myxomatous degeneration, and others of well-developed fibrous tissue. The diagnosis, thus far then, is fibromyxoma, the typical structure of the majority of innocent false neuromata (*Figs.* 158, 159).

FIG. 160.—Cyst wall; oil-immersion; magnification $\frac{1}{12}$. Highly cellular area showing resemblance to sarcoma.

Alexis Thomson,[1] in his monograph on this subject, has collected five cases of solitary

fibromyxomata from his own clinical experience, and reports five more from the literature.

The important practical point about this tumour is as to whether or not it is undergoing sarcomatous degeneration, as these fibromyxomata so frequently do. There are a couple of masses of cells staining deeply with hæmalum and quite definitely of a different

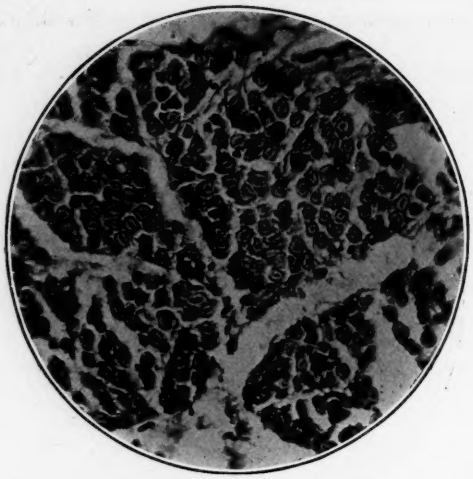

FIG. 161.—Transverse section of nerve-trunk above the cyst. Stain: hæmalum and eosin. Shows absolutely normal nerve tissue.

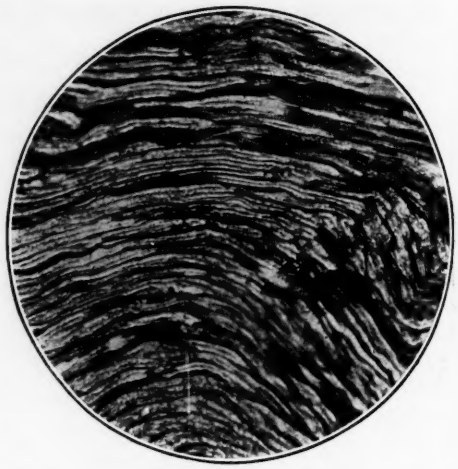

FIG. 162.—Longitudinal section of nerve-trunk below the cyst. Stain: hæmalum and eosin. Shows normal nerve tissue.

type from the fibroma cells of the main tumour. Powell-White does not consider that they are sarcomatous, but does not explain their presence. *Fig.* 160 shows a view of one of these areas under an oil-immersion lens. A few of the cells are undoubtedly lymphocytes, and perhaps we have here merely a small lymphatic vessel packed with lymphocytes. It would appear, therefore, that though this tumour was essentially innocent in its inception, the presence of possible early sarcomatous change cannot be denied, and that, although the prognosis would appear good from histological evidence, the case still requires very careful observation.

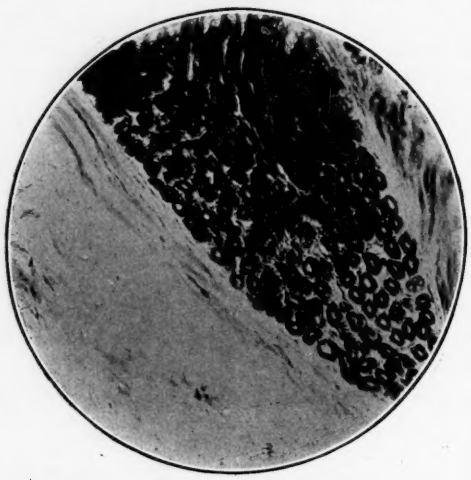

FIG. 163.—Transverse section of nerve-trunk below the cyst. Stain by Weigert's method. Shows perfect myelination.

2. *Transverse section of nerve above tumour.—Fig.* 161.

This, except for a slight increase of interstitial fibrous tissue, is perfectly normal.

3. *Transverse section of nerve below the lesion.—Fig.* 162.

This is also perfectly normal histologically, except for two or three small masses of polymorphonuclear leucocytes found lying in between the fibres of one nerve bundle. The portion of section shown in the microphotograph is longitudinal to the long axis of the nerve, but shows perfectly normal tissue.

The Weigert section shows no sign whatever of any myelin degeneration (*Fig.* 163).

The sections above and below the cyst would, then, tend to confirm the view of the innocence of the tumour, and the perfect Weigert staining confirms the lack of any clinical evidence of loss of conduction.

CONCLUSIONS.

1. That a hæmorrhagic cyst of spontaneous origin arising in a peripheral nerve may be innocent.

2. That, in the absence of more definite evidence of sarcoma, such as infiltration of the nerve above and below the lesion or adherence to surrounding structures, it would have been advisable in this case merely to puncture the cyst and remove as much as possible of its wall without interfering with the continuity of the nerve bundles, thus avoiding the risk of incomplete regeneration after resection and end-to-end suture.

HISTORICAL SURVEY.

The occurrence of solitary fibromyxomata of peripheral nerve-trunks, though comparatively rare, is probably not extremely so. The subject does not seem to have been at all completely reviewed since Alexis Thomson[1] published his classical monograph in 1900. This surgeon is, however, able to describe five cases of his own, and has collected five cases from the literature up to that date. One of these latter presents features closely resembling the case described above, and perhaps merits transcription here :—

"This case is recorded by Surgeon Lieutenant-Colonel Hatch. A healthy-looking man, age about 40, complained of a tumour at the back of the left thigh of ten years' duration. At first it gave him no inconvenience. About a month before admission to hospital it became slightly painful. A tumour the size of an orange was found at the back of the thigh at the junction of the middle and lower thirds. The skin over it was tense and shining. The swelling was globular, firm, smooth and slightly elastic, very movable from side to side but not up and down. If the leg was flexed the tumour could be moved more readily. The limb was not wasted. Pain was felt at the site of the tumour and down the leg while walking, which made the patient limp a little. There was no tingling sensation. The femoral glands were not enlarged. All the organs were healthy. A longitudinal incision 5 in. long was made over the tumour ; the flexor muscles were dissected off the surface. The tumour was slightly lobulated and had a bluish appearance ; towards the lower end a yellow spot was seen, and here there was slight bulging. Continuing the dissection up and down, the swelling was found to be connected with the sciatic nerve ; a few veins and nerve fibrils ramified over the surface. A small puncture accidently made on the surface allowed pure blood to escape with considerable force ; the opening was closed with forceps, and the nerve fibrils which were in contact with the surface were very carefully separated on both sides. The sac was then completely evacuated and the trunk of the nerve which was spread out on its deep and anterior surface was defined and the sac removed. A skein of fibres which had been cut near the upper end of the cyst was sutured. The sac had a thin wall, apparently continuous with the sheath ; it contained pure blood, a little fibrin, and hæmatoidin crystals. Recovery was quite satisfactory."

Unfortunately no histological examination is reported of this case. The decision to perform a conservative operation must also have been easier here as the cyst was not so intimately surrounded by nerve-fibres as in the present case.

Thomson only reports one other cyst, a case of Zum Busch's. This was a lesion of the ulnar nerve in a patient, age 30, who had had two injuries to the elbow ; a probable T fracture of the lower end of the humerus in childhood and a more indefinite injury five weeks before he came under observation. There were signs of ulnar paralysis, and the cyst was found to contain "yellowish, jelly-like material resembling synovial fluid". The cyst was evacuated and its walls were sponged with corrosive sublimate. The paralysis disappeared and the patient resumed his occupation of furniture polishing in two months after operation.

Here again, apparently no histological diagnosis was attempted, and it is quite open to doubt as to whether the lesion was neoplastic or traumatic in its origin.

In the course of a search through the literature since 1900 I have not found any

report of a solitary cystic fibromyxoma of a peripheral nerve. The characteristic tumour of this type, as one finds it in the generalized form described by Von Recklinghausen, is solid in consistence.

Solitary fibromyxomata have been described by Foote[3] and by Gatch and Ritchey,[4] two specimens being reported by each. Three of these arose in relation to the brachial plexus, and are of interest in that they were large masses of new growth spreading irregularly between muscle planes, but showing their innocence by absence of invasion of muscle or other tissues. Kerr[2] in 1914 described what he believed to be the largest fibroma on record. It was a pure fibroma arising from the sciatic nerve, weighed 1 lb. 3 oz., and measured 6 in. by 3 in.

The histological diagnosis of such tumours—with reference to innocence or malignancy—seems to have presented difficulties before now. Foote reports that his first case was returned by the histologist as sarcoma, but the course of this case and the histological examination of his second case led to further sections being taken of the first, with the result that both his tumours were eventually considered to be innocent in type.

As regards the etiology of fibromyxomata, some observers consider that trauma plays an important part in their inception. They base this opinion on the fact that it is in the nerves which are most exposed to slight repeated traumata that these growths arise. Common opinion seems to be that the median is the nerve most frequently attacked. The sciatic also seems a favourite site.

Recurrence after operation is rare, and seems thoroughly to justify a conservative line of treatment in the absence of any definite macroscopic signs of malignancy. Foote mentions an interesting case reported by Bruns in which the surgeon, after the successful removal of an innocent tumour of a nerve in the foot, was required to operate on a similar growth in the sciatic of the same limb.

The absence of any loss of motor or sensory power of the nerve involved in innocent fibromyxoma seems to be universally agreed upon, the symptoms in the most severe cases being a variable, but generally slight, amount of tingling and 'pins and needles' in the sensory distribution of the nerve.

My thanks are due to the following for facilities and assistance in the report of this case: Mr. E. E. Hughes, Professor J. S. B. Stopford, Dr. Charles Powell-White, and Mr. Harry Platt.

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CONGENITAL DIAPHRAGMATIC HERNIA.

By J. B. HUME, London.

A review of the literature on this subject would show a wide divergence of opinion on the etiology of the various types of diaphragmatic hernia, and on the treatment that should be adopted. The scope of this paper is to attempt to define, first, the various types from the standpoint of the pathological anatomist, and to offer an explanation of their mode of origin ; and secondly, to indicate the lines on which surgical treatment may be attempted. A complete report of one case is included, and reports on the examination of two other specimens of the condition.

DEVELOPMENT OF THE DIAPHRAGM.

The diaphragm arises by modification of the septum transversum of the early embryo. This septum is mainly a mesoblastic vehicle for the ducts of Cuvier from the body wall to the heart. It occupies an oblique plane, sloping downwards and forwards from the cervical region, immediately dorsal to the heart. From this position it makes a gradual descent, reaching its final level about the third week of intra-uterine life.

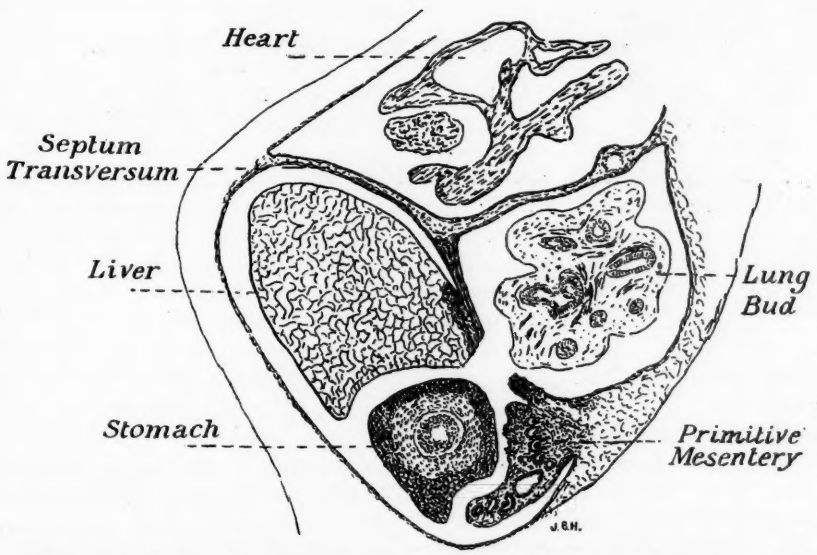

Fig. 164.—Sagittal section of 11·5 mm. embryo through the hiatus pleuroperitonealis. (⅔ obj.)

During the third week it has a posterolateral opening on either side, the hiatus pleuroperitonealis, through which the lung buds pass upwards, as the septum transversum descends ; the pleural cavity thus being an extruded portion of the cœlom (Keith). As the septum transversum descends, mesoblastic cells in the lower dorsal region, representing the cephalic end of the primitive mesentery, proliferate, and, bridging across the opening, establish a connection with the septum transversum (*Fig.* 164).

The diaphragm is thus constituted of a ventral portion derived from the septum transversum, and a dorsal portion derived from the primitive mesentery. In the primitive mesentery, near its free border, is placed the developing œsophagus and stomach.

In the fourth week the hiatus pleuroperitonealis is closed by a double fold of pleura and peritoneum. Muscle fibres are now present in the septum, but not in the membrane closing the hiatus. This can be seen macroscopically from the fifth to the twelfth week as a transparent triangular area situated between the costal and spinal muscle origins (*Fig.* 165).

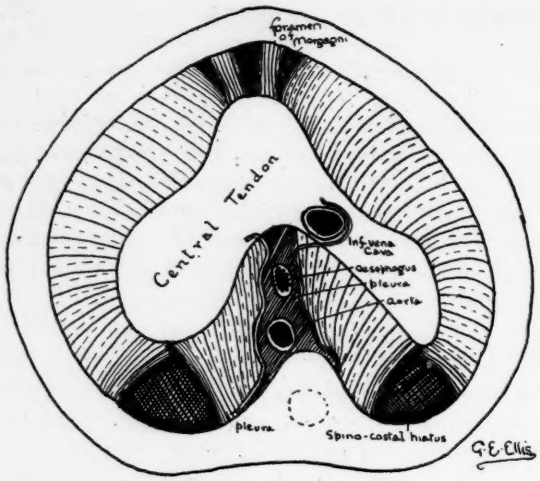

FIG. 165.—The thoracic aspect of the diaphragm, showing the position of the hiatus pleuroperitonealis (spinocostal hiatus).

The thinnest portion of the rest of the diaphragmatic sheet is the central area of each dome. The right dome is completely filled by the liver, while the left contains a small portion of liver, the stomach, and coils of intestine of the proximal and distal loops of the mid gut, which are undergoing rotation about the axis of the vitelline artery. The grouping of intestine in this region is due to the fact that this is the most roomy part of the abdominal cavity, the anteroposterior diameter of the lower abdomen being much less, and the pelvis merely a potential space.

Mode of Origin of Congenital Diaphragmatic Hernia.—It is probable that this arises at the period of development just described.

TYPES OF CONGENITAL DIAPHRAGMATIC HERNIA.

Four types may be described: (I) *Hernia through the hiatus pleuroperitonealis.* (II) *Hernia through the dome.* (III) *Hernia through the œsophageal orifice.* (IV) *Absence of the left half of the diaphragm.*

Type I. **Hernia through the Hiatus Pleuroperitonealis.**—This is, if fœtal cases are included, the commonest type. It is, however, rarely met with in adult life. Keith collected 21 cases from the medical museums of London, and of these only 2 survived more than a few weeks after birth. It is suggested that the intestine follows the lung bud through the hiatus at the time when the former leaves the cœlomic cavity; or that it passes through, from lack of intra-abdominal space, before the pleuroperitoneal membrane closes the hiatus. That it is a fact that the hernia occurs at an early stage is shown by the opening retaining the shape of the hiatus pleuroperitonealis, and by the absence of any sac.

The admitted greater frequency on the left side is due to the mass of liver protecting the right hiatus. The lung, on the affected side, is partially under-developed in all cases. The intestine is invariably in a condition of incomplete rotation, and it is common for the greater part of both large and small intestine to be intrathoracic.

Type II. **Hernia through the Dome.**—This may occur as a true hernia (in other words, a hernia with a sac), or as a false hernia.

Pressure of abdominal organs on some weak point of the diaphragm may produce a hernia, either before or after birth. Such cases, in which sacs of thinned-out peritoneum and diaphragm were present, have been described by Lawrence and Petit. A generalized bulging of one dome, with a consequent abnormally high situation, is described by radiologists, and named 'eventration' (Sailer and Rhein, Bayne Jones). It is debatable whether this should be classed as a hernia at all.

The above explanation may be true of some cases, but certain facts suggest an alternative explanation now brought forward. The herniated structures are usually the stomach and omentum, or, in addition, a portion of the transverse colon, with perhaps coils of small and large intestine as far as the splenic flexure.

The arrangement of the large intestine is important ; it is found to the left and partly in front of the small intestine, in the position occupied before the normal axial rotation of the gut is completed. The inference is that the hernia occurred at the time when the rotation was taking place (that is between the fifth and eighth weeks), either by the gut becoming included in the junction between the dorsal and ventral portions of the diaphragm, or by pressure and movement causing the primitive diaphragm to give way. Incomplete rotation of the gut thus favours the formation of hernia, and the herniation of the gut obviously brings rotation to an end. In this sense incomplete rotation is at the same time the cause and effect of a diaphragmatic hernia.

Case 1 illustrates this, while cases in which this condition is described are reported by Beckman and Duval. The latter records repeated attacks of appendicitis occurring in a boy, age 12, with a diaphragmatic hernia. The symptoms were referred to the chest, and the appendix was found below the left clavicle.

A partially detached lobe of the liver is a frequent content of hernias through the dome. Keith records it in several fœtal cases ; and Monks, at an autopsy on a man of 43, who died of pneumonia, found a portion of the left lobe, together with the stomach and transverse colon. Oui and Devulder found two openings, one in each dome, in a full-term male fœtus, abnormal lobes of the liver being responsible for both. The liver was in three portions, one in the right side of the thorax, a central abdominal portion, and one in the left side of the thorax. The liver in its development expands into the substance of the septum transversum, and these cases are explained by a complete penetration of the septum having taken place, leading to a corresponding deficiency of the diaphragm. The stomach, developing immediately posterior to the septum, probably becomes included in the attachment of the primitive mesentery to the septum transversum.

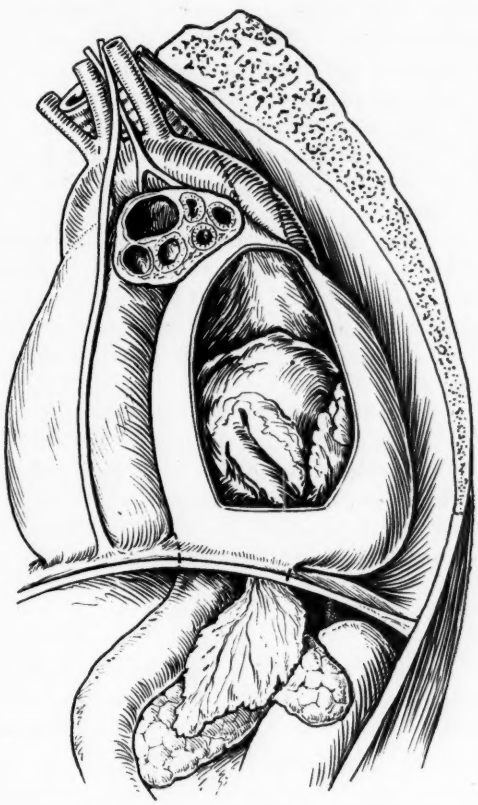

FIG. 166.—Hernia through the œsophageal orifice. Lateral view, semidiagrammatic. The dotted lines show the termination of the œsophagus.

Type III. **Hernia through the Œsophageal Orifice.**—As in the dog-fish, in the early human embryo the stomach occupies a retro-pericardial position. In the later stages of development in the mammalia, a migration of the stomach towards the tail occurs, accompanied by a corresponding elongation of the œsophagus. In the human embryo this migration is almost complete before the final constitution of the diaphragm. When the tailward migration fails, the stomach instead of the œsophagus is found in the position of the normal œsophageal opening in the diaphragm. This opening is in consequence enlarged to approximate to the calibre of the stomach, though some degree of constriction is usually present. A portion of the cœlom becomes separated off, and encloses the stomach in a peritoneal sac. As the stomach completes its descent it carries this portion of peritoneum down with it, and a remnant of it may be seen in the fœtus as a small finger-like process, to one or both sides of the œsophagus, and named the para-œsophageal recess. A small portion of stomach or intestine may pass up into one of these peritoneal diverticula. *Case* 2 (*Fig.* 166) illustrates this failure of migration, the stomach lying in a sac in

the posterior mediastinum, and the œsophagus ending just below the bifurcation of the trachea.

One other extreme case has been recorded by P. Bailey, while Huffman described a true hernia in the same position, the œsophagus running along in the posterior wall of the sac for a short distance, before entering the stomach 3 cm. above the diaphragm. A case operated on by Mathews and Imboden is probably similar.

The œsophageal opening is normally oblique, and placed in the thick muscular portion just above the crura. Hernia through this orifice is more likely to be due to these developmental causes than to a gradual stretching from increased intra-abdominal tension, whilst trauma is more likely to affect the costal region.

The present unsatisfactory subdivision between congenital and acquired (or traumatic) diaphragmatic hernia is largely due to the fact that authors assume a hernia occurring through the œsophageal orifice to be an acquired one. Bevan states that "acquired hernias of the diaphragm always occur at the œsophageal orifice, just as inguinal hernia occurs at the external abdominal ring, the œsophageal orifice being the normal weak point in the diaphragmatic wall." Lawford Knaggs reports 8 such cases, 6 of them having a definite sac, which he adds, "is conclusive evidence that the rupture has been acquired"; and in the other two cases says, "but since the hernia took place through a dilated œsophageal orifice in each case, there is a strong presumption that both were acquired." Such a view is scarcely tenable if the embryology above described is accepted. *Case* 2 is strongly illustrative of this point.

Type IV. **Absence of the Left Half of the Diaphragm.**—Complete absence of the left half of the diaphragm is not infrequently found in fœtal cases. The whole diaphragm to the left of the œsophageal opening and the left crus is absent. Parietal pleura and peritoneum form a continuous sheet. Abnormal lobes or semi-detached portions of the liver are frequently found, and the greater part of the intestine, in a partially rotated condition, lies in the chest. (See *Case* 3 and *Figs.* 168 and 169.) Such a condition is almost always incompatible with life; though it is recorded that one boy lived to the age of 17 (Beckman).

Unusual Forms of Diaphragmatic Hernia.—Hernias have occurred through other openings in the diaphragm, but are of extreme rarity. The whole literature contains but 8 recorded cases of hernia through the foramen of Morgagni—the small interval for the passage of the superior epigastric artery between the sternal and costal slips. A hernia accompanying the sympathetic trunk under the internal arcuate ligament is twice recorded. Hernia into the pericardium has also been met with (Stoeber).

Occurrence.—The writer has collected from the English, French, and American publications 35 cases of undoubted congenital diaphragmatic hernia during the years 1910 to 1921, many of which are quoted in the text. Previously, Balfour in 1869, Lawford Knaggs in 1904, and Keith in 1910, have published collected cases of diaphragmatic hernia. The 35 cases fall into the types above described as under:—

Type I.—Hernia through the Hiatus Pleuroperitonealis. 1 case.

A full-term fœtus.

Type II.—Hernia through the Dome. 18 cases.

True hernia (i.e., with sac), 6 cases; False, 9; Not stated, 3.

Right dome, 2 cases; Left, 16.

Age incidence:—20 hours to 20 years, 6 cases; 20 to 40 years, 1 case; 40 to 55 years, 11 cases.

Incomplete rotation of gut, 3 cases.

Type III.—Hernia through the Œsophageal Orifice. 12 cases.

True hernia, 6 cases; False, 2; Not stated, 4.

Age incidence:—7 to 20 years, 4 cases; 20 to 40 years, 1 case; 40 to 60 years, 5 cases; 60 to 77 years, 2 cases.

Type IV.—Absence of Left Side of Diaphragm. 4 cases.

Fœtal cases, 3; 1 boy, age 17.

Clinical Course and Complications.—In the great majority of these cases, those discovered accidentally after death from some other cause being excepted, there were symptoms referable to some degree of obstruction. This was less marked in *Type III* than in *Type II*, and in some cases only appeared from time to time.

An unusual number of complications were met with in the latter type. Mention has already been made of a case of chronic inflammation of an intrathoracic appendix. Meyer reports a case of volvulus of the stomach (Willett reported one in 1897); Stewart, of strangulation of the intestine; Lennox Gordon, of perforation of a gastric ulcer into the right thoracic cavity; and Mercadé, of perforation of a herniated stomach by a gunshot wound.

The only complication amongst the œsophageal type was one case of tetany (Greig).

Notes on Surgical Treatment.—Surgical treatment is unlikely to be required for hernia through the hiatus pleuroperitonealis (*Type I*). In those cases that survive more than a few days, the opening is large enough to prevent obstruction. Under certain circumstances such a condition might demand a herniotomy, but no attempt would be made to transfer the intestine to the abdominal cavity.

All cases in which the condition is suspected should have a radiographic examination made during the passage of an opaque meal. Reference to the relative positions of the œsophagus and the stomach shadow will show the situation of the opening in the diaphragm. If some hours later, the meal is seen in an intrathoracic large intestine, it is improbable that any surgical procedure, beyond enlargement of the orifice as a measure in cases of obstruction, would be of any avail.

In cases in which some operative procedure is decided on, an extensive thoracotomy, by removal of a large portion of the 7th rib and wide retraction of the parts, would give an excellent exposure of the upper surface of the dome, and a view of the thoracic contents.

Dilatation of the intrathoracic portion of the stomach sometimes calls for operation, particularly this has occurred in cases of *Type III*. The stomach should, if possible, be emptied by means of an œsophageal tube, reduced as far as possible from the thoracic aspect, and its margins sutured to the opening in the diaphragm (Beckman, Downes). This is at best a palliative measure; another that has been tried is suturing the viscus to the anterior abdominal wall, through another incision (Mathews and Imboden).

In cases of *Type II*, when only a small portion of the stomach is herniated and can be readily reduced, an attempt may be made to close the orifice by suture. Some authors report a measure of success with this procedure (Frank).

NOTES OF CASES.

Case 1.—**Diaphragmatic hernia illustrative of *Type II*, with incomplete rotation of the intestine.** (Published by kind permission of Dr. H. H. Tooth.)

Clinical History.—H. T., a boy, age 6, was admitted to hospital on account of an attack of acute abdominal pain. Vomiting followed, and continued for 48 hours. The temperature was 97°, the pulse 104, and respirations 40. There was no history of any comparable attack. Six months previously he had been knocked down by a vehicle and sustained concussion, being unconscious for fourteen days.

The physical signs were those of a left-sided pneumothorax: succussion splash, metallic sound, and bell-sound all being present. The heart was displaced to the right, its left border being behind the sternum. The percussion note was impaired below the angle of the left scapula. The metallic and bell-sounds varied from time to time, sometimes being present and sometimes absent.

The report of an *x*-ray examination was "complete pneumothorax, left side, the left diaphragm considerably higher than the right." Paracentesis thoracis was performed in the 5th left intercostal space, air bubbled out, and some brownish material was withdrawn. Four hours later the patient suddenly died.

Post-mortem.—*Fig.* 167 illustrates the arrangement of parts in the specimen obtained. A circular opening, 2¼ inches in diameter, was present in the left dome of the diaphragm, to the left and slightly in front of the œsophageal orifice. Its edges were thick, rounded, and muscular, and perfectly smooth. The opening was subdivided into two compartments by a horizontal band

FIG. 167.—Hernia through the left dome. The liver has been removed.

of adhesions stretching across its left margin to the 8th left costal cartilage. (This band forms the anterior boundary of the opening in *Fig.* 167, the anterior compartment having been destroyed.)

The stomach passed into the thorax through the posterior compartment, being looped up as in the fœtal specimen represented in *Fig.* 168. With it was the ascending colon, the great omentum, and the gastrohepatic omentum. The body of the stomach filled the greater part of the left pleural cavity; in addition to the marked dilatation, the muscular coats were greatly thickened. It contained over a pint of partially digested food. A constriction was present at the junction of the body and the pyloric portion where it re-passed under the band of adhesions.

A condition of incomplete rotation of the gut was present. The large intestine from the cæcum to the splenic flexure lay in a U-shaped loop in the thorax, the commencement of the ascending colon and the end of the transverse colon being in the posterior part of the orifice. The apex of the cæcum was directed upwards, passing through the anterior compartment (in the figure it is shown drawn over to the left). The appendix lay on the right side of the mesentery of the small intestine, and below the ileocæcal junction. The root of the mesentery of the small intestine, spread out fanwise, ended over the lower pole of the right kidney. The head of the pancreas projected above the duodenum, and under the Spigelian lobe of the liver, from which it was separated by a pocket of the lesser sac of the peritoneum. With this exception the lesser sac was completely intrathoracic.

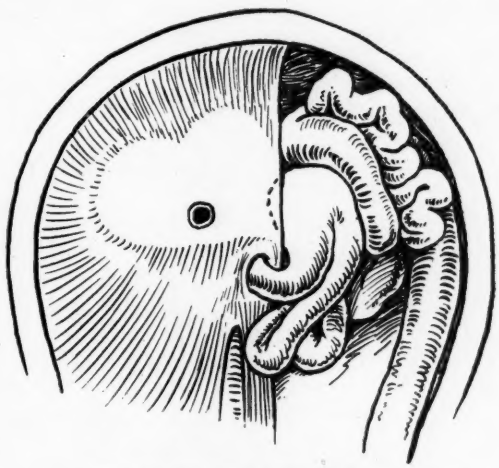

FIG. 168.—Absence of left half of the diaphragm, abdominal aspect, diagrammatic.

The left lung was collapsed and lay with the root in the normal position. Sections showed it to be atelectatic. The pleura and peritoneum were continuous; there were no signs of old or recent pleurisy.

(This and the two following specimens are now preserved in the Museum of St. Bartholomew's Hospital.)

Note on Case I.—Objection might be raised to this case being classed as a congenital one, in view of the history of trauma. The arrangement of the intestine, however, indicates that it had always occupied this position, the process of axial rotation being arrested in the position seen in the specimen. The fan-like termination of the root of the mesentery, and the reversal of the course of the small intestine present in this case, are characteristic of cases of incomplete rotation, and are strong evidence against the cæcum having been drawn up into the thorax. The margins of the opening in acquired cases usually show either scar-tissue or adherent omentum; are frequently irregular in shape; and are more common in the costal zone. In these cases the lung is compressed, and situated in the upper part of the pleural cavity, not, as in *Case* 1, atelectatic and at the lung root.

The second case is that of a man, age 56, brought as a subject for dissection to the anatomical department of St. Bartholomew's Hospital. Death was certified as due to bronchitis and heart failure.

Case 2.—**A hernia occurring through the œsophageal orifice.** (*Fig.* 166, *Type III.*)

A large opening, 2½ inches in diameter, surrounded by thick, rounded muscle, is present in the position of the œsophageal opening in the diaphragm and opposite the 10th thoracic vertebra. Through this opening the peritoneal cavity communicates with a large sac, situated in the posterior mediastinum, and containing the body of the stomach and the greater part of the gastrohepatic and gastrocolic omenta.

The sac consisted of thickened peritoneum, with external coverings of two layers of mediastinal fascia. Anterior to it was the pericardium, posteriorly the aorta, and to left and right the mediastinal layers of the pleuræ. The great vessels were not altered in position. The left lung was rather smaller than normal, its lower lobe was compressed. The œsophagus, passing down behind the root of the lung, ran for a short distance in the posterior wall of the sac before entering the stomach. The cœliac axis artery was given off at its normal level; its coronary branch and the two epiploic arteries passed through the opening in the diaphragm in their corresponding

omenta, to reach the stomach. No obstruction was present at the junction of the body and pyloric portions of the stomach. The body of the pancreas was bent at an angle opposite the diaphragmatic opening, but did not pass into the thorax.

No other abnormalities were discovered.

Case 3.—**A fœtal specimen illustrating *Type IV*, that of the absence of the left half of the diaphragm.**

Fig. 168 indicates the extent of the diaphragmatic loss, and shows the stomach passing into the thorax immediately to the left of the œsophageal opening. The fundus is directed upwards and to the right. The opening was partially blocked by an almost detached portion of the left lobe of the liver.

The only portions of the alimentary canal remaining in the abdomen were the duodenum, and the colon below the position of the splenic flexure.

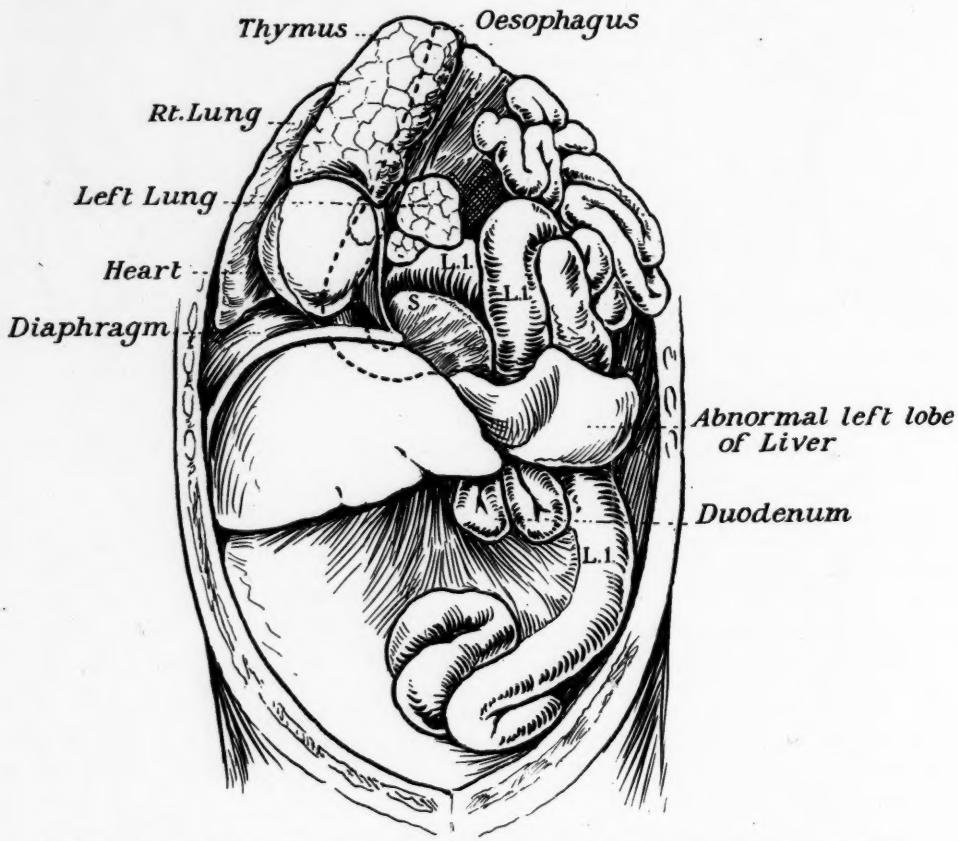

FIG. 169.—Absence of left half of the diaphragm. The course of the œsophagus is shown by dotted lines. (S) Stomach. (L. I.) Large intestine.

Fig. 169 shows the colon arching over the small intestine, the cæcum being below and to the right. The spleen lay in a sac formed by its passage through the posterior mediastinum into the right pleura.

There was no trace of any diaphragmatic remnant on the left side, the parietal pleura and the peritoneum forming one continuous layer.

SUMMARY AND CONCLUSIONS.

1. Diaphragmatic hernia may be classified as :—
   a. Traumatic : (i) true, (ii) false.
   b. Congenital : (i) true, (ii) false.

2. Congenital hernia occurs through the left dome most commonly, to a less extent through the œsophageal orifice. In other situations it is but rarely met with in adult life.

3. Hernia through the hiatus pleuroperitonealis takes place before the closure of that opening in the embryo.

Hernia through the dome of the diaphragm is due to some primary congenital ectopia of viscera, occurring at the time of formation of the diaphragm, and sometimes associated with incomplete rotation of the intestine.

Hernia through the œsophageal orifice is due to failure of the tailward migration of the stomach, or in some cases to the persistence of a para-œsophageal recess.

4. Surgical treatment is palliative only. Thoracotomy is the route of election.

My thanks are due to Sir Arthur Keith, Professor G. E. Gask, and to my colleagues, Drs. T. H. G. and L. R. Shore, for valuable assistance and advice in the preparation of this paper.

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RE-SUTURE OF PERIPHERAL NERVES.

By JOHN S. B. STOPFORD, Manchester.

We are confronted from time to time with patients who have received no benefit from the suture of a peripheral nerve, and it is then necessary to decide whether, in the case of certain nerves, to advise the patient to submit to re-suture, or to consider the condition as irreparable. This subject is of greatest importance in connection with the ulnar or median nerves, since in the case of the musculospiral or even the sciatic nerve alternative orthopædic measures offer such good functional results that a re-suture rarely needs to be entertained. Information about the prognosis after re-suture of a nerve is so scanty that at present it is not easy to decide when such a procedure is justified; and therefore it may prove helpful to record a series of cases in which this operation has been performed, to see if any serviceable deductions may be drawn from an analysis of them.

It is not intended in this paper to discuss the obvious contra-indications for re-suture, as irreparable arthritic changes or contractures, nor to mention technical points in the operation of suture of a nerve, but rather to discover the principal factors which influence regeneration and the subsequent occurrence of a good functional result.

During the last five years I have had the opportunity of observing the results of re-suture in 14 patients, the nerves affected being: median 5; ulnar 7; musculospiral 1; external popliteal 1. In all except one of these (No. 2 in the following table) it has been possible to keep the patients under observation for a sufficiently long period to be able to see the end-result. The principal features to be noticed in the fourteen patients are recorded briefly in the table on next page.

From an analysis of this series it is clear that several important factors bearing upon the prognosis have to be considered, and the more significant of these will be discussed in rotation.

1. *The interval which has elapsed between the reception of the injury and the date of the re-suture.*

From the present series it would appear that this is an important factor, since out of 7 patients in which the interval exceeded two years there were 6 complete failures. In all six failures the interval was approximately three years or longer. In a large series of 271 cases of secondary suture[1] the opinion was formed that a delay *per se* of twelve to eighteen months had no appreciable effect upon the extent of recovery. If the interval exceeded that time the prognosis was not so good when the suture had been performed in the distal part of the limb; whereas, in the proximal part, a delay of two or three years did not prejudice the chances of success. The number of re-sutures is too small to judge the influence of level, but in other respects the results seem to support the conclusions arrived at from the investigation of a large number of cases of secondary suture.

It is of interest to notice that the four best results were obtained in patients where the delay was between twelve and eighteen months.

Re-suture does not appear to be a hopeful procedure if three years have elapsed since the time of the injury; a suggestion as to the cause for a graver prognosis after the longer delay will be made at a later stage.

2. *The cause of failure after the original suture.*

It is not always possible to determine this; but it is obvious that the original cause must frequently have an important influence upon the prognosis after re-suture. In two patients the two extremities of the nerve had broken apart after the first operation, and in another the failure was probably due to faulty technique, conditions which cannot in

themselves prejudice the success of a re-suture. In one case the original operation consisted of the insertion of a nerve-graft; this case has been included, although strictly speaking the second operation cannot be called a re-suture, since the general conditions are so similar to those prevailing in the rest of the series. In 6 others the failure was due apparently to intraneural fibrosis, which is usually most severe and extensive after sepsis, but may occur irrespective of this. In five of the six patients in which a failure is recorded after re-suture, intraneural fibrosis seemed to be responsible for the failure after the original suture.

TABLE GIVING RESULTS OF RE-SUTURE IN 14 PATIENTS.

Note.—P.R.T. = Pronator radii teres; F.S.D. = Flexor sublimis digitorum; F.P.D. = Flexor profundus digitorum; F.L.P. = Flexor longus pollicis; F.C.U. = Flexor carpi ulnaris; A.M.D. = Abductor minimi digiti.

CASE NO.	NERVE INJURED	SITE OF INJURY	INTERVAL BETWEEN DATE OF INJURY AND RE-SUTURE	PROBABLE CAUSE OF FAILURE AFTER FIRST OPERATION	RESULT OF RE-SUTURE
1	Musculospiral	Arm	40 months	Sepsis and intraneural fibrosis	Failure
2	Median	Elbow	13 months	Separation of ends	P.R.T., F.S.D., F.P.D., F.L.P. show voluntary power. Slight recovery of analgesia
3	Median	Forearm	33 months	Intraneural fibrosis	Failure. Amputation of hand subsequently
4	Median	Wrist	26 months	?	Recovery of analgesia and some recovery of anæsthesia
5	Median	Arm	14 months	?	All muscles show voluntary power. Recovery of analgesia
6	Ulnar	Arm	14 months	?	F.C.U. A.M.D., interossei show voluntary power. Recovery of analgesia
7	Ulnar	Arm	14 months	?	F.C.U., F.P.D., A.M.D. show voluntary power. Some recovery of analgesia
8	Ulnar	Forearm	34 months	Bad technique	Failure
9	Ulnar	Elbow	35 months	Intraneural fibrosis	Failure
10	Ulnar	Axilla	21 months	Intraneural fibrosis	F.C.U., F.P.D. show voluntary power
11	Ulnar	Arm	17 months	Sutures broke away	F.C.U., F.P.D. show voluntary power
12	Median	Forearm	72 months	Intraneural fibrosis	Failure
13	Ulnar	Forearm	23 months	Nerve-graft	F.C.U., F.P.D. show voluntary power. Recovery of analgesia
14	External popliteal	Thigh	45 months	Intraneural fibrosis (6 inches resected at re-suture)	Failure

In all, at the operation of re-suture, an extensive length, averaging two to two and a half inches, was excised in order to attempt to get above the most severe fibrosis, and in one (No. 14), where very marked intraneural changes were encountered, Mr. Platt excised six inches.

From a histological study of excised pieces of nerve, and more extensive examinations of the proximal part of the nerve in irreparable cases where amputation has been found

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8	Ulnar	Forearm	34 months	Bad technique	Failure
9	Ulnar	Elbow	35 months	Intraneural fibrosis	Failure
10	Ulnar	Axilla	21 months	Intraneural fibrosis	F.C.U., F.P.D. show voluntary power
11	Ulnar	Arm	17 months	Sutures broke away	F.C.U., F.P.D. show voluntary power
12	Median	Forearm	72 months	Intraneural fibrosis	Failure
13	Ulnar	Forearm	23 months	Nerve-graft	F.C.U., F.P.D. show voluntary power. Recovery of analgesia
14	External popliteal	Thigh	45 months	Intraneural fibrosis (6 inches resected at re-suture)	Failure

In all, at the operation of re-suture, an extensive length, averaging two to two and a half inches, was excised in order to attempt to get above the most severe fibrosis, and in one (No. 14), where very marked intraneural changes were encountered, Mr. Platt excised six inches.

From a histological study of excised pieces of nerve, and more extensive examinations of the proximal part of the nerve in irreparable cases where amputation has been found

necessary, quite severe intraneural changes have been traced as far as eight inches above the level of the lesion, and it seems probable that after sepsis they may extend to the spinal cord. From my own observations, I am of the opinion that one of the most frequent causes of failure after suture of peripheral nerves, following gunshot wounds, is the fibrosis in the nerve-trunk, around bundles and even within bundles surrounding the individual nerve-fibres. In an appreciable proportion these intraneural changes are so extensive that the most liberal resection practicable fails to get above them.

3. '*Bad shunting.*'

The risk of efferent fibres growing down to afferent terminals or vice versa, which with the most perfect surgical technique must occur to some extent in almost all secondary sutures, is still greater after re-suture, since a greater length is excised under the latter conditions, and the intraneural anatomy is still more disturbed. This factor is of less importance in the case of the musculospiral nerve, which is so largely composed of efferent

FIG. 170.—Section of upper sacral region of spinal cord of a rabbit 29 days after division of sciatic nerve in the gluteal region. Note chromatolysis and feeble staining of most of the cells in anterior cornu at (A).

[*The section is from an experimental investigation at present in progress which has been aided by a grant from the Royal Society.*]

fibres, but is of great significance in the median or ulnar, in which nerves afferent, efferent, and sympathetic fibres are in more equal proportion. We are liable to imagine that there is slight change in the intraneural pattern as a nerve extends to its distribution, and that the bundles formed in the proximal part of the nerve persist more or less distinct with only slight exchange of fibres as they pass to their destination; yet Langley and Hashimoto[2] and Compton[3] have shown conclusively that all nerve-trunks in the limbs have an internal nerve plexus before they give off branches. In the large nerves which are considered in this paper the internal plexus involves the bundles and not merely a few nerve-fibres, but from the observations of Compton it appears that these plexuses are composed largely, if not entirely, of motor fibres.

These anatomical studies do not minimize the importance of the adoption of every possible surgical technique to avoid distortion during the performance of a nerve suture; but they do show that, except in a few circumstances, the best technique cannot prevent some bad shunting, and that this factor becomes of greater significance when the resection is extensive.

4. *The effect of a third section of the nerve-trunk upon the cells of the anterior cornu and posterior root ganglion.*

This factor has a more theoretical interest than the former three, but nevertheless it must have some practical bearing. It has long been known that injury to an axone induces a reaction in the cell from which it arises, whether the cell of origin be in the anterior cornu or posterior root ganglion. These changes, which consist chiefly of central chromatolysis (*Fig.* 170), swelling of the cell, and excentration of the nucleus, are more profound if the nerve is lacerated or torn than if it is divided cleanly, and are more pronounced when the injury occurs in the proximal part of the limb than in the distal. Experimental work upon animals has shown that in the former position the changes may be sufficiently severe to cause complete destruction of some cells, whilst in the latter position no very definite reaction in the nerve-cells may be manifest. The stage of solution is apparent within two days, and persists for about three weeks, at the end of which time most of the cells commence to recover slowly. The period of recovery extends over a considerable time; Buzzard and Greenfield[4] state twenty to eighty days; but after amputation of part or the whole of a limb, changes have been found in the cells of the anterior cornu from three to seven months after the operation. In most cases of re-suture these reactions must occur three times, since injury to axones occurs at the outset and with resection of the nerve-trunk at each operation. The initial trauma—since in gunshot injuries the nerve is usually torn and lacerated—is likely to produce the most severe reaction, and if the injury is in the proximal part of the limb the results of the two resections cannot be disregarded entirely.

In the series published in this paper the reaction due to the additional resection does not appear to be of serious practical consequence, since in the eight cases in which regeneration has occurred after re-suture the extent of both motor and sensory recovery compares favourably with the end-results I have been able to observe in a large number of patients after the performance of secondary suture. In the case of the complete failures it is impossible, with any degree of accuracy, to decide whether this factor is partly responsible for the absence of regeneration, but I am inclined to regard the time element and the intraneural condition of the proximal segment as the most important causes of failure. It is possible that the more serious prognosis after a long delay may be due to the factor at present under consideration, since it has been shown experimentally that a greater number of nerve-cells degenerate and disappear after section of a peripheral nerve if union of the two ends does not take place, and that the recovery of cells in the anterior cornu and posterior root ganglia depends upon restoration of the continuity of the nerve-trunk.

I desire to express my gratitude to Mr. H. Platt for his co-operation in the work, and the opportunity to study his patients.

CONCLUSIONS.

1. Regeneration may occur, under favourable conditions, after the re-suture of a peripheral nerve.

2. The end results after successful re-suture are similar to those observed after a successful secondary suture.

3. The causes of failure seem to be the same as in secondary suture, with the addition of: (*a*) Greater disturbance of the intraneural anatomy by the further resection; (*b*) The

effect of a third injury to the nerve-fibres upon the cells in the anterior cornu and posterior ganglia.

4. Excluding complications, re-suture is contra-indicated ; (*a*) When more than three years have elapsed since the time of the reception of the injury to the nerve ; (*b*) When extensive intraneural fibrosis has been encountered at the first operation.

5. The imperfect recovery of function and sensation, which is almost invariably found, even under the most favourable circumstances, after secondary suture or re-suture, is chiefly due to : (*a*) Disturbance of the internal anatomy of the nerve-trunk ; (*b*) Intraneural fibrosis.

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AN INQUIRY INTO THE RESULTS OF THE OPERATIVE TREATMENT OF INTERNAL DERANGEMENT OF THE KNEE-JOINT.*

By PHILIP H. MITCHINER, London.

For the purposes of this inquiry, all cases of internal derangement of the knee-joint operated on in St. Thomas's Hospital during the preceding ten years, i.e., 1912–21, have been circularized and requested to attend hospital for inspection, or, if unable to attend personally, to write a truthful account of the present condition of the knee, and a brief history of its progress since operation.

Statistical Notes.—The total number of cases of internal derangement operated on in the period covered by the inquiry is 225; to all these cases inquiries were addressed, and replies were received from 134, or approximately 60 per cent. Of this number, between 80 and 90 attended for inspection, and were carefully examined as to the physical condition of both joint and limb, subjective and objective symptoms, and in most cases by radiographic examination also. The condition of the other joints, especially with regard to osteo-arthritic changes, was noted in every case.

Of the total number of cases, 182 were males and 43 females, or a proportion of four males to one female. It is further of some interest to note that there is no increase of the number of female cases in the last five or six years, which the entry of women into more strenuous occupations might have led one to expect.

Only one fatal case occurred in the series, that of a man from whose joint two loose bodies were extracted, and who three days later developed a suppurative arthritis of the knee, with subsequent pyæmia, and death on the tenth day, in spite of the fact that the affected joint was removed almost as soon as suppuration manifested itself.

Classification.—In regard to the various types of internal derangement met with, the following classification has been adopted for the purpose of this paper, based on the appearances found in the joint at operation :—

Group *A*.—Loose body in the knee-joint.

Group *B*.—Torn or displaced semilunar cartilage (only including those cases where actual evidence of lesion was observed at operation).

Group *C*.—Hypertrophied synovial fringes.

Group *D*.—No definite intra-articular lesion found.

Group *E*.—Torn crucial ligaments.

Relative Frequency.—The relative frequency of these lesions was found in this series to be as follows :—

Total cases 225	*Group A*	39	cases	=	17·3	per cent
	„ *B*	125	„	=	55·5	„ „
	„ *C*	27	„	=	12·0	„ „
	„ *D*	30	„	=	13·3	„ „
	„ *E*	4	„	=	1·8	„ „

It will thus be seen that *Group B* cases were more than the total of all the other groups together, and it is to be regretted that a further subdivision of this group into tears of

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the semilunar cartilage and of the coronary ligament (with displacement of the cartilage) was not carried out.

Operation Incisions.—Two operative routes had been used in opening the knee-joint: (1) A lateral incision over the affected cartilage, either transverse or vertical in direction; (2) A vertical median incision with longitudinal splitting of the patella. Inasmuch as only the former incision was used until 1914, it is perhaps unfair to make a comparison of the results achieved by these two operative routes; the following observations may, nevertheless, prove of interest and value.

For the purposes of operation there is no doubt that the transpatellar route allows of a much more efficient view of the joint for exploratory purposes, and furthermore admits of the complete removal of the semilunar cartilages: a point of some importance in view of the fact that in over 5 per cent of cases subsequent trouble resulted from the posterior fragment of the semilunar cartilage left *in situ* after removal of the major part through the lateral incision, trouble which, moreover, was cured by subsequent excision of the remaining portion in many such cases. This remaining portion tended to calcify and act as a source of irritation and frequent effusions into the knee-joint, subsequently forming a starting-point for osteo-arthritic changes, or a source of a loose body.

In regard to the immediate after-results of operation—and this period covers, as is shown later, one of over twelve months' duration—there is no doubt that the knee opened by the transpatellar route is more painful and more liable to effusion, and one might think, therefore, more liable to be the seat of lasting after-complications; but this is not borne out by our investigation.

The ultimate results are, if anything, more satisfactory after the transpatellar operation; no impairment of movement has been noted, and the risk of subsequent trouble from osteo-arthritic changes is certainly no greater; indeed, in cases where the semilunar cartilage needs removal, it is less—as has been pointed out above—than after operation by the lateral route.

A large number of patients operated on by the lateral route, moreover, complain of complete loss of sensation over the head of the tibia and around the ligamentum patellæ, with, in some cases, tingling and pain on kneeling, a symptom which is still present as long as ten years after operation. Examination shows there is in many cases a definite area of anæsthesia over the inner condyle of the tibia, and a larger area around which only protopathic sensation is present.

These phenomena, although not in any case accompanied by clinical trophic lesions of the skin, are a source of discomfort to the patient, and inasmuch as they are due to section of the internal cutaneous branch of the anterior crural nerve (medio-cutaneous branch of femoral nerve) at the site of operation, can easily be avoided by use of the transpatellar route.

Results of the Inquiry.—The actual results in the 134 cases from whom replies were received, or who were examined, are appended in the following table, where the results in each group have been shown under the following headings:—

1. *Good.*—Where the patient not only has no complaint to make of the joint, and is able to obtain full use on all occasions with no untoward results, but also writes, or uses expressions, with regard to the success of the operation, such as, "The operation was an unqualified success", "I have not had any trouble with my knee since operation", "I have never had cause to think of my knee since", etc.

2. *Fair.*—Where the joint, although giving no trouble during the patient's ordinary everyday life, yet causes pain or has an effusion as the result of over-exertion.

3. *Unsatisfactory.*—Where the joint is in the same condition as before operation, is a continual source of trouble from pain and effusion, or is even worse than before operation.

It may be urged against this method of classifying results, that no account has been taken of the actual results of clinical examination; and in reply to this it must be admitted that several cases in which a certain amount of post-operative osteo-arthritic change was present have been included under the heading 'good'. The defence is that such patients made no complaint of this condition up to the time of, or at, inquiry; and since the

result from the patient's standpoint is most important, it was considered that this was the most satisfactory method of classification. A further point in its favour is that only 87 of the 134 cases included actually presented themselves for examination.

TABLE SHOWING THE RESULTS IN EACH GROUP.

GROUP TOTALS	GOOD		FAIR		UNSATISFACTORY	
	Number	Per cent	Number	Per cent	Number	Per cent
Group A, 23	14	60·9	5	21·7	4	17·4
,, *B*, 74	57	76·7	14	19·2	3	4·1
,, *C*, 16	6	37·5	7	43·8	3	18·7
,, *D*, 18	5	27·7	3	16·8	10	55·5
,, *E*, 3	2	66·6	1	33·3	—	—
TOTAL 134	84	62·7	30	22·4	20	14·9

It will thus be seen that the percentage of good results in the series is 62·7, fair 22·4, and unsatisfactory 14·9 ; moreover, the best results (76·7 per cent good in *Group B*) were obtained where definite lesions of the semilunar cartilages were present, and the worst (55·5 per cent unsatisfactory in *Group D*) where no definite lesion was observed, and where —in spite of the joint being apparently normal—the semilunar cartilage was excised at operation (see remarks on *Group D* below).

The joint was definitely worse in two cases only. In one where a loose body had been removed from an osteo-arthritic joint in 1912, there was now very marked osteo-arthritis, and seven loose bodies in the joint. It may be remarked in passing that this patient was regularly employed in carrying loads up ladders, and was in the habit of ' putting his knee in again ' when it locked, which it did frequently ! The second case was one in *Group D* where, in spite of no definite lesion being seen, the internal semilunar cartilage had been removed ; there was a complete flail joint, due to laxity or atrophy of the crucial and other ligaments, and the joint could be dislocated in all directions ; the limb was much wasted, and the man could only get about when using a knee-cage.

Notes on Cases in the Various Groups.

Group A.—There was nothing particular to note in this group save perhaps the greater tendency of these cases to develop osteoarthritic changes.

Group B.—Of these cases, 69 showed lesions of the internal and 4 of the external semilunar cartilage : a proportion of approximately seventeen to one in favour of the internal cartilage in frequency.

Group C.—It is interesting to note that, subsequent to operation, 5 cases developed tuberculous disease either in the joint itself or elsewhere in the body, and that in all these cases the joint still gives trouble.

Group D.—Three cases in this group developed renal disease, and one diabetes, and it seems probable that in these cases the synovial thickening was of a toxic nature, and comparable to the toxic œdema of shins met with in such cases. One case developed acute nephritis immediately after operation, and in this case the change was assuredly of this nature ; this man now reports that at present both his renal and knee conditions are quiescent, but that exacerbations of renal trouble are frequently accompanied by swelling in the knee-joint.

It is, furthermore, a noteworthy fact that although, amongst the 18 cases traced in this group, in only 4 was the surgeon content to close the joint on nothing abnormal being found, yet these 4 cases are included among the 5 ' good ' results. The remaining ' good ' case was one in which hypertrophied synovial membrane only was removed. The remaining 13 cases, in which the internal semilunar cartilage was partly or entirely excised, have all given subsequent trouble.

Group E.—Only 3 of the 4 cases comprising *Group E* can be traced. The fourth one

was of great interest, in that wire loops were inserted to replace a hopelessly disrupted posterior crucial ligament, and it is to be regretted that this case cannot be traced.

Among the whole 225 cases only 2 joints suppurated, one being the fatal case quoted elsewhere, and the other following a hæmatoma in the joint. This latter case was treated by gauze packing daily, and now, three years after operation, the patient is able to follow his occupation, and has a useful limb with about 50 per cent movement at the knee-joint and only very slight lateral mobility.

Clinical Notes on Cases Examined. — Post-operative osteo-arthritic changes, or aggravation of osteo-arthritic changes noted in the joint at operation, as judged by comparison with the opposite knee-joint, were noted in 50 per cent of the cases examined; it is, however, of interest to find that in many cases where marked signs of such changes were present, the patient neither complained of, nor had noted, any disability in the joint; indeed, in only about 12 per cent of these cases was any complaint made by the patient. In no case was the change sufficient to cripple the patient entirely.

In several cases, where no complaint was made, *x*-ray examination showed linear calcification in the remains of the posterior part of the internal semilunar cartilage, which is therefore a presumable source of trouble.

It was not found that the cases treated by the transpatellar route showed any greater percentage of arthritic changes, or any greater severity of changes, than those met with in joints opened by the lateral incision; although several of the latter type of cases dated back to 1912, as against 1914 only for the former.

Pain and effusion in the joint subsequent to operation, occurring in attacks and following unusual or undue exertion on the part of the patient, was noted or complained of in nearly all cases operated on in the last three years, i.e., 1919–21. This led to inquiry being made among all the other patients operated on at earlier dates where no such complaint was now made, and it was elicited that in the majority of these cases, now quite cured, pain and effusion in the knee-joint had occurred on exertion for from two to three years after operation, and that in many cases this effusion had taken considerable time to be absorbed. Such unwelcome occurrences became less frequent towards the end of the second year after operation, and then ceased, so that from the third year onward the patient could indulge in all forms of exercise without any untoward results.

In those cases where the joint had been fixed by splinting for any length of time after operation, there was frequently marked and persistent muscular wasting around the joint, and in all such cases the convalescence had been much prolonged, and the period during which attacks of pain and synovial fluid effusions were liable to occur was protracted, or even permanent.

Only in the case where hæmarthrus and subsequent suppuration supervened, was any ill effect noted from non-fixation of the joint after operation; and early movement and light massage or faradic electrical treatment seemed to have benefited the patients in promoting rapid absorption of effusions, amelioration of pain, and normal return of tone to the muscles around the joint.

Lastly, it was found that most of the women, and many of the men (who as policemen had to take part in physical drill), complained of pain when the knee was in extreme flexion, as on kneeling or squatting back on the heels, and inability to start rising from these positions. In all cases where this disability was complained of, there were osteo-arthritic changes in the joint, though in the majority nothing else was complained of except the pain on flexion.

CONCLUSIONS.

It would appear that the following conclusions can be drawn from the facts elicited in the examination of the foregoing series of cases:—

1. That as regards the actual route selected at operation, the transpatellar is the most satisfactory in all respects.

2. That no method of splinting is necessary or advisable to secure fixation of the

knee after operation ; early movement, combined with electrotherapeutic measures, are beneficial in promoting early absorption of effusions.

3. That the full benefit of the operation is not to be expected for from two and a half to three years after its performance.

4. That those cases where a definite lesion of the intra-articular structure is present give far more satisfactory results (76·6 per cent in cases of damage to the semilunar cartilage, and 60·9 per cent in those of loose body) after operation than where no definite lesion can be found (37·7 per cent with synovial fringes, and only 27·7 per cent where no lesion is seen at operation).

5. That when nothing abnormal is found on the joint being opened, the best course to adopt is to close the joint without interfering with the intra-articular structures.

On reviewing the whole of the facts set forth in the foregoing article, it would seem that operative interference in cases of internal derangement of the knee is justifiable, if not indeed desirable, in all cases where a diagnosis of a definite lesion of any of the intra-articular structures can be hazarded with any degree of certainty, and where the consequent disability is sufficient to prevent the patients carrying out efficiently their daily avocation.

MULTIPLE POLYPI OF THE STOMACH (GASTRITIS POLYPOSA): WITH THE REPORT OF A CASE.

By G. PERCIVAL MILLS, Birmingham.

There are three fairly clearly defined types of the so-called polyadenoma of the stomach:—

1. The single large polypoid tumour, usually growing near the pylorus and frequently becoming malignant. Cases have been reported by Bret,[1] Finnig and Friedenwald,[2] Gibson and Blake,[3] Ledderhose,[4] Ruggles,[21] and others.

2. Polyadenoma of the 'Brunnerian' type, the structure of which resembles that of Brunner's glands normally found in the duodenum. This type causes a considerable thickening of the mucous membrane over a limited area, and like the first type, frequently becomes malignant. It was first described by Hayem[5] and again more fully by Socca,[6] who considered it to be due to a congenital malposition of Brunner's glands.

3. A form of polyposis first fully described by Menetrier[7] in 1888 and called 'polyadenome'. In this type the tumours are multiple, sessile or pedunculated, and usually scattered widely over the surface of the stomach. Their microscopical appearance suggests that they are localized overgrowths of the mucous membrane, and they are seldom associated with carcinoma.

Cases of the first two types are well defined, but the third type has given rise to much controversy, and the true nature of the morbid process is still uncertain. It is frequently referred to as 'gastritis polyposa' or 'diffuse polyposis'. The former term is undesirable, as it suggests an inflammatory origin which is not yet proved; the latter possesses the merit of being non-committal.

My attention was directed to the subject by the following case.

Case Report.—Mr. L., age 60. Engaged in retail trade.

History.—The patient had been in perfect health up to seven months before I saw him. About this period he began to get occasional attacks of diarrhœa, and once or twice he vomited after food. The attacks of diarrhœa alternated with constipation, so that a growth of the colon was suspected. There was no pain. More recently he had suffered from a feeling of nausea after food, and complained "that it did not go down properly". He had completely lost his appetite and had lost considerably in weight. At no time during his illness had there been any pain, and he had only vomited half a dozen times during the seven months.

Examination.—This showed a spare man of the wiry type with obvious signs of recent wasting. He had a regular slow pulse and his arteries were reasonably soft for his age. His tongue was clean. The abdomen showed nothing abnormal, no distention, local swelling or splashing. Per rectum the prostate was a little enlarged.

On screening the patient after a barium meal, there was seen the typical picture of pyloric stenosis—a very broad stomach with the pylorus pushed over to the right, and strong deep peristaltic waves producing no evacuation whatever. Four hours later three-fourths of the barium was still in the stomach.

Diagnosis.—Carcinoma of the pylorus.

Operation.—A paramedian incision was made above the umbilicus. A small, hard, nodular growth was found at the pylorus. The pyloric glands were enlarged but soft, and there were a few soft enlarged glands in the gastrohepatic omentum. In handling the stomach a soft slippery substance was felt inside, about at the middle of the body of the viscus. It was obviously attached to the stomach wall, but only loosely, so that it easily slipped away under the fingers. A polypoid growth, possibly secondary, was suspected, and the resection was planned to include its removal. The usual partial gastrectomy for carcinoma was done. On dividing the body of the stomach to the left of the palpable polypus it was found that the whole body and fundus of the viscus was studded with small polypoid tumours varying in size from that of a split pea to a cherry. They were soft and velvety to the touch, and, while attached to the mucous membrane, were freely movable on the muscular wall. The smaller ones were sessile and appeared like a localized thickening of the mucous membrane, while the larger ones were pedunculated. They were so numerous that it was extremely difficult to avoid them in dividing the stomach. It was obvious that nothing

short of a subtotal gastrectomy would secure their removal, and this was not attempted. About half the stomach was removed, the upper part of the opening sutured, and the lower part united to the jejunum through the transverse mesocolon in the usual way. The duodenal opening was closed. The patient left the nursing home on the fourteenth day, taking ordinary diet without pain or discomfort, and seven months later when last heard of he remained well.

THE SPECIMEN consists of a part of the duodenum, the pylorus, pyloric antrum, and a few inches of the body of the stomach, together with pyloric and a few omental glands. It was packed with gauze and hardened before being cut, so as to preserve its shape.

At the pylorus is a hard, nodular, infiltrating growth, sharply limited on the duodenal side, but encroaching a little on to the pyloric antrum. In the hardened specimen the stenosis is not so evident as it was clinically and at the operation, in spite of the fact that the whole specimen has shrunk to about two-thirds of its original size. The tumour has ulcerated, but there is no fungous outgrowth into the lumen. It is of the infiltrating type like an epithelioma of the skin or tongue.

The polypoid tumours are entirely confined to the body of the stomach; there are none within three inches of the pylorus in the shrunken specimen. The large palpable one, originally about the size of a cherry, has shrunk very considerably, and many of the smaller ones, which originally appeared as sessile thickenings of the mucous membrane, can no longer be distinguished. There is no sign of ulceration or infiltration in any of the polypoid tumours, and from their absence in the pyloric antrum they would appear to have no connection with the carcinoma.

MICROSCOPIC EXAMINATION.—The pyloric tumour is a columnar-celled carcinoma with areas of lymphatic infiltration in which the cells are polygonal, taking their shape from mutual pressure. The muscular coats of the stomach are involved, but the peritoneum appears to be intact over the growth. The polypoid tumour has the appearance of a localized overgrowth of the gastric mucous membrane and is everywhere separated by submucous tissue from the muscular coats. In its deeper parts the glandular tubules are fairly regular and normal in appearance; in the superficial parts they are very irregular and many small cysts are present. This layer forms the actual surface of the tumour, i.e., there is no separate covering of normal gastric mucous membrane. There is a slight fibrous core which appears to be continuous with the submucous coat. This core branches and extends between the glandular tubules. The individual cells are of normal columnar type with basal nuclei, and the basement membrane is everywhere intact. The stroma is vascular, but there is no round-celled infiltration or other sign of inflammation. The mucous membrane between the tumours is normal. There is no evidence of chronic gastritis.

Diffuse polyposis of the stomach is evidently a rare disease, and, as most of the recorded cases have been found unexpectedly at post-mortem examinations, clinical records of the disease are still rarer. The older literature on the subject is confused by the inclusion of cases of single polypus, innocent or malignant, and of certain other gastric disorders.

The rarity of true polyposis is well brought out by some figures quoted by Myer.[8] In 7500 post-mortem examinations only 4 cases of gastric polypus were found (Obruchow Krankenhaus); in several Russian hospitals the percentage of cases found post mortem varied from 0·007 to 0·04, and this included polypi of all kinds. Again, of 22 cases of gastric polypus collected from the literature by Ebstein,[9] only 3, or approximately one-seventh, could be described as cases of diffuse polyposis. Verse[10] collected 55 cases of polypus of the alimentary canal, of which only 4 were in the stomach. Further evidence is produced by Balfour[11], who recently published a case and stated that it was the first one observed in 8000 operations for diseases of the stomach at the Mayo clinic.

The earliest case of which I can find a record was reported by Cruveilhier[12] in 1833. In this case forty scattered polypi were discovered at a post-mortem examination, and he notes that they were attached to the mucous membrane, but moved freely on the muscular coats.

The first serious attempt to describe the disease was made by Menetrier in 1888. He gave a very minute and careful description of it, and enunciated certain views on its origin which have been followed by many subsequent writers. He classified the cases into those in which there were scattered polypi over a large area of the stomach wall ('polyadenomes polypeux') and those in which a large number of polypi were closely aggregated into a sort of plaque ('polyadenomes en nappe'). He further attempted to distinguish cases in which the overgrowth affected the deeper parts of the glands from those in which the ducts were mainly affected. Although his nomenclature suggests to the English ear a form of new growth, he appears to have regarded the overgrowth of mucous membrane as inflammatory

in origin, and he lays particular stress on the fact that the mucous membrane between the tumours always shows evidence of chronic inflammation. He is equally insistent on this point in the case of a stomach which contained one solitary polypus. Most of his cases showed signs of advanced arteriosclerosis, and he regards this as an important etiological factor. He reports 7 cases, but a careful consideration in the light of more recent knowledge compels me to exclude three of these from the category of polyposis. One was a single polypus, and one is described as having the mucous membrane thrown into longitudinal folds rather than polypi; while other evidence, such as intense hepatic cirrhosis, suggests that it was a case of chronic alcoholic gastritis. The third case that I exclude was almost certainly a 'leather-bottle stomach'; the stomach is described

TABLE OF 19 CASES OF MULTIPLE

Author	Date	Sex	Age	Mode of Diagnosis	Symptoms	Evidence of Other Disease
1. Cruveilhier[12] ..	1833	—	—	P.M.	——	——
2. Cruveilhier[12] ..	1833	—	—	P.M.	——	——
3. Richard[13]	1846	M.	51	P.M.	Diarrhœa	Chronic pleurisy
4. Brissaud[14]	1885	M.	79	P.M.	6 months' loss of appetite and wasting	——
5. Lœudet	—	—	—	P.M.	——	——
6. Menetrier[7]	1888	F.	62	P.M.	——	Phthisis. Tuberculous ulcer in colon. ? Carcinoid in small intestine
7. Menetrier[7]	1888	F.	40	P.M.	——	——
8. Menetrier[7]	1888	F.	52	P.M.	——	Cerebral hæmorrhage
9. Menetrier[7]	1888	M.	35	P.M.	——	Left hemiplegia
10. Menetrier and Clunel[15]	1907	M.	52	P.M.	——	Pulmonary tuberculosis
11. Menetrier and Clunel[15]	1907	F.	75	P.M.	No gastric symptoms	Atheroma
12. Menetrier and Clunel[15]	1907	F.	73	P.M.	No symptoms	——
13. Wegele[16]	1909	F.	59	Polyp found on gastric tube	——	——
14. Chosrojeff[17] ..	1912	M.	36	Polyp in wash out	Hæmorrhage. Loss of weight. Abdominal pain	——
15. Heinz[18]	1912	F.	35	Operation	——	——
16. Myer[8]	1913	M.	—	Polyp in wash out	20 years' chronic gastritis	Syphilis
17. Von Saar[19]	1918	F.	56	Operation	——	——
18. Balfour[11]	1919	M.	31	*X*-ray and operation	3 years' abdominal pain and loss of appetite	Had been treated for phthisis. Wassermann negative
19. MacPhedran[20] ..	1921	F.	50	*X*-ray	Pain after meals and constipation	——

as being very small, with *all* its coats enormously thickened, and there were secondary carcinomata in the liver.

Including Menetrier's remaining 4 cases, I have been able to collect from the literature 19 cases only of multiple gastric polypi, i.e., cases in which there were at least two tumours. Single tumours and those of the very rare Brunnerian type, which are quite different, are excluded. Of these 19, however, 5 cases had less than six tumours present, so that only 14 can strictly be described as diffuse polyposis.

A brief table of the cases is appended. Many important facts are unfortunately missing, especially in the earlier cases.

POLYPI OF THE STOMACH.

Morbid Anatomy	Microscopic Appearance
40 scattered polypi. Fixed in mucous membrane. Free from muscles	——
95 scattered polypi, but pyloric area free	——
50 scattered polypi the size of peas	——
200 small polypi. Areas round pylorus and cardiac orifice free. No chronic inflammation of mucous membrane	——
150 polypi, mainly on greater curve. Sessile and pedunculated	——
40 polypi size of pea to hazel nut on lesser curve and posterior surface. Mucous membrane appeared normal	'Polyadenome polypeux'. Mucous membrane showed signs of chronic inflammation
3 polypi	As above
Aggregated mass of polypi in plaque 8 cm × 4 cm. and single isolated polyp size of pea	'Polyadenome en nappe'. Mucous membrane showed signs of chronic inflammation
Carcinoma lesser curve 4 cm. from pylorus. Forty polypi, size of lentil to pea, mostly near carcinoma	Polypi as in *Case* 6. The growth on lesser curve was malignant
Numerous polypi size of lentil to hazel nut, and chiefly near the pylorus	As in previous cases, but with small mucinous cysts
5 polypi size of lentil to walnut near the lesser curve	Large polypi had fibrous core with mucous membrane of convoluted and cystic glands ten times the normal thickness over it. Small ones showed only the thickening of the mucous membrane
Pyloric carcinoma with single polyp near it	As large polypi above
Whole surface studded with small soft polypi	'Adenoma' with core consisting of muscularis mucosæ and fibrous tissue
Multiple polypi size of pea to hen's egg	'Polypi with carcinomatous metaplasia'
3 polypi near lesser curve. Appeared benign	Adenoma ? ? becoming malignant
Multiple polypi except near cardiac orifice and pylorus	——
Carcinoma of pylorus with a single polyp some distance away	Adenoma. No sign of chronic inflammation of mucous membrane
250 polypi about the size of hazel nuts, all within 5 inches of pylorus	Adenoma
No operation	——

In considering this table with my own case, certain points suggest themselves for discussion.

Age.—It has been often remarked that this disease mainly occurs in the aged, but this view clearly needs modification, for out of the 16 cases in which the age is known, 12 were not over sixty and 5 not over forty.

Symptoms.—The information on this head is very meagre, but it is evident from *Cases* 11 and 12 that the disease may exist without giving rise to symptoms at all, and it is significant that the first 12 reported cases were all discovered post mortem. In other cases there were symptoms directing attention to the stomach, usually dyspepsia and hæmorrhage, and, in the treatment of a supposed chronic gastritis by lavage, the first ante-mortem diagnosis was made (*Case* 13), for a portion of tumour was found on the stomach tube. In the last two cases the diagnosis was made by radiography, which showed a characteristic mottling of the barium shadow. My own case shows, however, that this is not always evident. In *Case* 18, Balfour was fortunately able to excise the whole of the affected part of the stomach, and this is, I believe, the first recorded instance of the deliberate diagnosis and radical treatment of the disease. Apart from radiography, the diagnostic point which Balfour chiefly stresses is the complete absence of free hydrochloric acid from the test meal.

Number and Position of the Tumours.—Of 19 cases in which the stomach was examined either at operation or post mortem, in 5 there were less than six tumours, leaving only 14 which could be described as diffuse polyposis. In only a few of these was the precise situation of the polypi stated, but in these the situation is rather striking. In 3 cases the tumours are described as being almost all near the pylorus, while in 4 others it is expressly stated that the pyloric area was free from tumours. The contrast is well brought out by a comparison of Balfour's case with my own ; in his, all the tumours were within five inches of the pylorus, in mine this was the only part of the stomach free from them. I can offer no explanation of this curious localization of the tumours. The greatest number of tumours counted in any one case was 250.

Association with Other Diseases.—Menetrier regarded arteriosclerosis as a cause of this disease and found it in most of his cases. It is not uncommon in middle-aged people of the hospital class. There was evidence of tuberculosis in 4 cases and of syphilis in one. Syphilis has also been suggested as a cause, but in Balfour's case the Wassermann reaction was negative. I do not think there is enough evidence for any of these diseases to be regarded as the cause.

Association with Carcinoma.—There were only 4 cases in the whole series of 20 (including my own) in which polypi were associated with carcinoma, and in each case the carcinoma was at or very near to the pylorus. The arrangement of the polypi differs in each case. In *Case* 9 there were multiple polypi near the growth, in *Case* 12 there was a single polypus near the growth, in *Case* 17 a single polypus some distance from the growth, and in my own case there were multiple polypi all distant from the growth.

One's first thought on finding polypi associated with carcinoma is that they are secondary growths by permeation or implantation. On this view their peculiar arrangement in my own case is very difficult to explain, and the tumours, whatever they are, are certainly not in the least like secondary carcinomata. Alternatively, carcinoma may have started as a malignant transformation of one of a number of pre-existing polypi. P. Menetrier and Clunel, in reporting *Case* 12, bring strong evidence in favour of this view. In this case there were two tumours on opposite walls of the stomach near the pylorus. One was a typical polypus and the other a larger sessile tumour adherent to the muscular coats. On section it proved to be early carcinoma. In my case, however, the carcinoma was of the flat epitheliomatous type and could hardly have originated from a polypus ; moreover, the nearest part of the polypoid area was four inches away. In this case the carcinoma may have been a coincidence. One can say at any rate, that malignant change in gastric polypi is not very common, since, in twelve post-mortem examinations at an average age of 58 years, carcinoma was present in only two cases.

Nature of the Tumours.—It is a striking fact that the work of Menetrier in 1888 still remains the most complete account of these tumours. His name, ' polyadenome ', suggests

a new growth, but his description certainly gives the impression that he regarded the tumours as inflammatory in origin, and he is very insistent in each case on the presence of signs of chronic inflammation of the intervening mucous membrane. He is equally insistent on this point even in the case of a stomach which contained one single polypus and which is therefore excluded from the table above. Though I hesitate to disagree with so careful an observer, I am not convinced of this chronic inflammation. No other writer appears to have found it, and von Saar definitely states that in his case it was not present. In my own case Dr. Lawrence Ball, who kindly examined the specimen for me, assures me that the mucous membrane between the tumours was perfectly normal, and he examined it specially for signs of chronic inflammation.

As regards the tumours themselves, Menetrier's description still holds the field, though later knowledge has shown that the two types of glandular overgrowth, which he attempted to distinguish, frequently co-exist in the same case. Of the later writers, Wegle, von Saar, and Balfour describe the tumours as adenomata, while Chosrojeff describes his case as " polypus with carcinomatous metaplasia in part ". The tumours are certainly not inflammatory in the sense of being infective granulomata. The glandular overgrowth is such that the mucous membrane becomes some ten times its normal thickness, and the tubules become irregular and frequently cystic. Although a certain degree of round-celled infiltration has been described by Menetrier, it is clear from his excellent pictures that the thickening is due to glandular overgrowth and not to inflammatory exudate. So far the tumour fairly justifies its title of adenoma. On the other hand, it has no capsule and not even a clearly defined margin, for its edge gradually merges into the normal mucous membrane, in which respect it resembles an overgrowth due to chronic irritation.

One is familiar with the fact that overgrowth of squamous epithelium is produced by chronic irritation, and in certain cases by infection. The common wart on the skin is an example, and though I believe no organism has been isolated, its infectious nature is well recognized. There seems no reason why a similar infection should not produce overgrowth of the cells of a mucous membrane and, if so, such overgrowth would take much the form of these polypoid tumours. It would begin with a localized thickening of the mucous membrane (sessile stage), and when this became big enough to drag on the stomach wall, it would become polypoid. Finally, when of considerable size, it would drag down some of the submucous coat also, forming the fibrous core of the larger tumours so well described by P. Menetrier and Clunel.

In view of the absence of a capsule and the blending of the tumour with the normal mucous membrane, I think these growths should be described as papillomata rather than as adenomata, and I am convinced that they will eventually prove to be something in the nature of infective ' warts ' on the mucous membrane of the stomach.

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THE APPLICATION OF THE WEDGE PRINCIPLE IN THE FASHIONING OF A TIBIAL 'BRIDGE' GRAFT.

By R. E. KELLY, Liverpool.

The weak point in all sliding bone-grafts has always been their fixation. It has been generally conceded that a firm fixation gives the best results, although some authorities have stated that a too firm fixation is deleterious on account of the destruction of the bone-forming cells by excessive pressure. A moment's consideration of the actual pressure exerted by the muscles on the broken ends of any fracture ought to convince anyone that the pressure cannot be too great or the fixation too perfect.

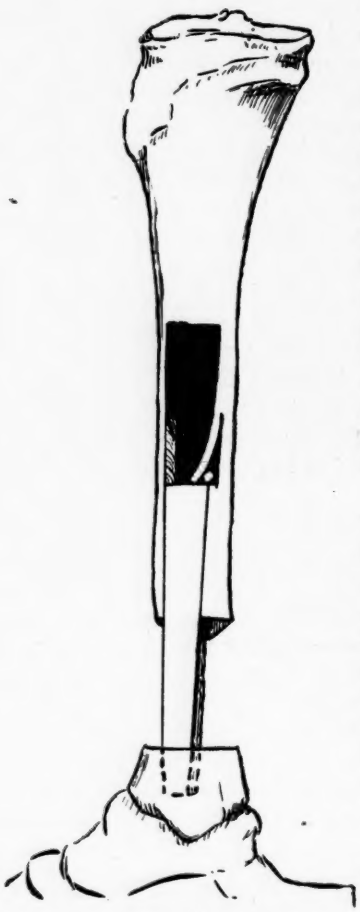

Fig. 171.—Illustrating the method of applying the bridge graft.

If the surgeon uses a twin saw and cuts his graft with parallel sides, it is obvious that the bed is wider than the graft by the thickness of two saw-cuts. If he elects to bevel the sides of such an inlay, he certainly will get a closer union; but to ensure absolute contact and firm fixation, the bevelled graft must be fixed by pegs or sutures. Obviously, a better fit could be obtained by making the inlay exactly the width of the bed, but that would necessitate cutting the graft from the opposite limb. A 'bridge' graft, fashioned after the method of Hey Groves (the cricket-bail graft), is difficult to make, requires careful fitting, and is exceedingly difficult to insert. The usual method of splitting the fractured bone in order to get the 'cricket bail' in place sometimes requires great force, and may even result in such splintering that the fixation becomes imperfect.

In a short paper in the British Journal of Surgery, Vol. vii, No. 28, I described an operation for the relief of slipping peroneal tendons. Here a tiny graft of the fibula was cut with double-wedged sides. Mere pushing backwards of the graft fixed it firmly in its new position without the aid of a peg or suture. The application of this wedge principle may be used in any sliding graft. The inlay is fashioned in the form of a long wedge, so that, in moving it to its new position, it is gripped along its whole extent by the bed. The diagram (*Fig.* 171) serves to illustrate the method. I also append *x*-ray photographs of a patient on whom I operated last year.

Mr. X., age 34, was knocked down by a char-à-banc, sustaining a bad compound comminuted fracture of the lower ends of the left leg. He thinks that the wheel went right over his left leg. The wounds were excised, together with innumerable small contaminated fragments of the tibia. After a prolonged convalescence of a year, he had recovered, with overlapping of the fibula and non-union of the tibia, the ends of this bone being about 1½ in. apart. The destruction of so much tibia was accounted for by the loss at the first operation, and the further subsequent removal of loose and necrosed fragments. At one time amputation was seriously considered, but as he retained a good blood- and nerve-supply to the foot, one refrained from the major operation in the hope of grafting

later on. The position at the time of grafting (October, 1921) was as follows: Overlapping of the fibula; contact, but no bony union, between the upper fibular fragment and the lower end of the tibia; fair movement at the ankle, and an intact foot, but quite useless for weight support (*Fig.* 172). There was marked atrophy of the bones.

Operating with a tourniquet, a long incision was made over the internal surface of the tibia, right down to bone, exposing almost the complete tibia. The periosteum was lifted with the flaps, and the whole operation carried out subperiosteally. If there is any virtue in the deeper layer of the periosteum from a bone-producing point of view, surely it is better to leave it *in situ* with its blood-supply intact, than to move it with the graft but sequestered completely from all vascular connections. I have so often seen the periosteum destroyed or torn off an inlay graft, despite special efforts made to preserve it, that I am convinced it is safer to leave it attached to the tissues overlying it.

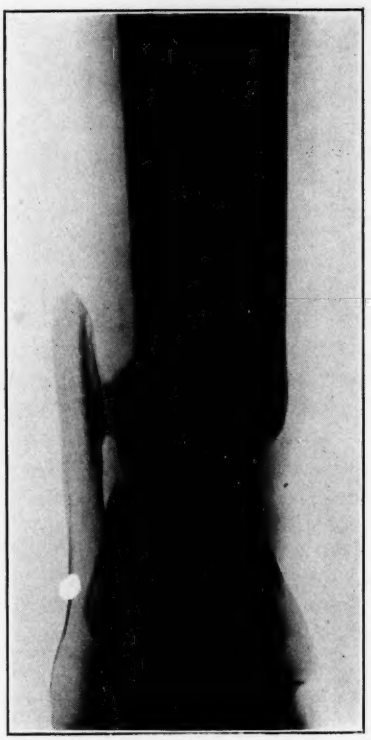

FIG. 172.—Before grafting.

FIG. 173.—Immediately after grafting.

When the whole internal surface of the tibia had been exposed, a wedge-shaped graft about 7 in. long was cut with an Albee circular saw, in such a way that the upper end was about $\frac{7}{8}$ in. wide, and the lower about $\frac{1}{2}$ in. In other words, the angle of wedge was about 1 in 20. Both saw-cuts were made at right angles to the internal surface of the bone. With a chisel the graft was freed from its bed and pushed down until its lower end impinged on and entered into a hole bored in the lower fragment of the tibia. This was done by tapping the top end of the graft, using a hammer and chisel in the same way that a joiner works, the flat of the chisel placed on the top of the graft and the hammer used to tap the back of the chisel. The graft soon begins to bite into its bed, the amount of transposition being of course dependent on the width of the saw-cuts and the angle of the wedge. If one knows these exactly, the amount of translation of the graft before it is tight may be calculated with mathematical precision.

Care must be taken that the wedge is not too blunt, otherwise the tibia may be

cracked before the required extension is attained. A further safeguard, however, to prevent the graft slipping upwards was made by placing a stop or catch at its upper end, A thin sliver of bone was cut with an Albee saw, about $\frac{1}{10}$ in. wide and $1\frac{1}{2}$ in. long, upon the side of the bed above the graft. This was sawn through at its lower end, but left attached at its upper. A chisel was inserted into the saw-cut, and the lower end of the slice levered inwards, and fixed into its new position by the insertion of a tiny fragment of bone. This latch prevented any movement upwards of the wedge (*see Fig.* 171). It could, of course, be done on both sides, but apparently this was not necessary. *Fig.* 173 shows an *x*-ray photograph taken immediately after the operation. Note the atrophic character of the graft. The 'latch' does not show well, but it can be faintly seen on the fibular side of the tibia. *Figs.* 174 and 175 were taken five and seven months later. The increase in strength and in thickness is well shown. Note also the

FIG. 174.—Five months after grafting.

FIG. 175.—Seven months after grafting.

development of buttresses. It is perhaps superfluous to add that all fibrous union, muscle, etc., were removed from between the fractured ends before sliding the bridge graft into its new position. Further, the rounded fibrous ends of the bone were sliced off.

I think this method of using a wedged graft to be of distinct value in cases of a similar nature where, from atrophy of the bone, a surgeon is disinclined to use a graft about whose stability he is somewhat uncertain. Obviously it may also be used for a recent fracture, the only point to remember being that the fractured ends must be in perfect anatomical apposition, and kept so whilst the graft is being cut. The portion of graft which is not used, namely, that from the lower end, may be put back in the space left in the upper fragment. If the angle of the wedge is correct, the fixation is perfect.

Joiners often use a double wedge. Any graft, even a parallel-sided one, may be sawn in two by cutting it diagonally. By sliding these wedges in opposite directions, the graft may be wedged in its bed so firmly that extraneous fixation is not necessary.

CARCINOMA OF THE BONE-MARROW.

By ALFRED PINEY, Birmingham.

I.—Introduction.
II.—Anatomy of the Bone-marrow.
III.—Blood-vessels of the Bone-marrow.
IV.—Lymphatic Channels of the Bone-marrow.
V.—Development of the Blood-forming Tissues.
VI.—Characters of the Blood Picture in Cases of Carcinosis of the Bone-marrow.
VII.—Mode of Spread of Carcinoma into Bone-marrow.
VIII.—Evidences of the Embolic Origin of Metastases in the Bone-marrow.

I. INTRODUCTION.

The existence of deposits of malignant tumours in the bone-marrow had been realized by morbid anatomists and surgeons a very considerable time before any definite explanation of the fact was available.

The early conception of the formation of deposits of cancer in the bone-marrow depended upon a belief in the existence of a 'cancerous diathesis', which was capable of manifesting itself in different regions of the body, either at the same time or successively. Sanson[1] described a case in which a woman, with a scirrhous cancer of the breast of less than a year's duration, broke one femur while moving in bed. During the manipulations necessary for the reduction of this fracture, the other femur broke. At autopsy, there were many cancerous deposits throughout the skeleton; almost all the segments of the vertebral column were filled with tumour tissue, as were also the frontal bone and the medulla of each femur. In the last-named position, Sanson states that the tumour appeared to have grown from within the bone outwards. He sums up the case as follows: "qui a offert l'example peut-être le plus complet de ce qu'on nomme la diathèse cancereuse".

The fundamental contributions to oncology which were made by Virchow made it necessary immediately to find some explanation of secondary cancerous deposits which did not depend upon the metaphysical conception of a 'cancerous diathesis'. It soon became obvious that the explanation of the process of formation of metastases was to be looked for in the blood or lymph. The conception of the formation of metastases by means of emboli consisting of cancer cells soon found abundant histological confirmation. The credit of pointing out the importance of a process other than embolism belongs to Sampson Handley. He has demonstrated that spread from a primary carcinoma of the breast is mainly by a process of 'lymphatic permeation; that is to say, growth takes place along the lymphatic channels from the primary focus outwards. In the course of such permeation, the epithelial cells may be destroyed by a process of perilymphatic fibrosis, or they may proceed directly along these channels until they reach another organ, where obstruction to their onward course will result in the formation of a metastatic nodule which is large enough to be detectable macroscopically. Obstruction to onward proliferation may take place at any part of the lymphatic system, and where this occurs there will be formation of a cancerous nodule, e.g., in the skin.

The purpose of this paper is the detailed discussion of the evidence which relates to the problem of metastases in bone. In order to attack this much-disputed question, it is necessary to have a clear understanding of the anatomy of the bone-marrow, and a knowledge of the origin of this organ in the embryo. In a paper read before the British Medical Association at Glasgow in July, 1922, the present writer has described the macroscopic anatomy of the bone-marrow at different ages, and only a brief summary of this subject can be given.

II. THE ANATOMY OF THE BONE-MARROW.

At birth all the bones of the skeleton except those of the cranium contain red marrow in which there is no fatty tissue either macroscopically or microscopically. As age advances, fatty tissue appears in the marrow, but is not present in equal amounts in all the bones.

The vertebræ, sternum and ossa innominata contain red marrow throughout life, and only microscopical amounts of fat are detectable even in advanced age. The ribs are also storehouses of cellular marrow throughout life, but in advanced age a patch of fatty tissue usually appears at the anterior end of each rib and extends for about one inch from the costochondral junction.

The long bones present changes which are rather more difficult to describe accurately and briefly. At birth the limb bones contain red cellular marrow in the diaphyses as well as in the epiphyses. The cellular tissue is divided into compartments by firm bony trabeculæ, and these take part in the series of changes which are normally associated with the attainment of the adult condition of the bone-marrow. Throughout childhood the marrow remains red, but fat is found in appreciable amount microscopically. It is not until the age of puberty is reached that macroscopically visible fat is found in the shaft. This first fat is visible just below the middle of the shaft in all the long bones and is surrounded by cellular marrow, which lies at the periphery of the medullary cavity. Extension of fatty change proceeds from this first formed mass of fat in both directions. The rate of spread in the distal direction is more rapid than in the proximal. Although the mode of fatty metamorphosis is the same in both the proximal and distal limb bones, there is one great difference, viz., the conversion into fat is complete more quickly in the distal bones. At the time when the whole of the radius, ulna, tibia and fibula are filled with fat, there is still a patch of red marrow at the upper end of each humerus and femur. This patch of red cellular marrow persists throughout life; microscopically it is obvious that there is a very considerable amount of fat even in this red patch.

The epiphyses of the long bones undergo a similar fatty metamorphosis, which is complete earlier than is the case in the shafts. The conversion of cellular marrow into fat is accompanied by disappearance of many of the bony trabeculæ in the shaft, but there is less disturbance of these structures in the epiphyses. The residual patches of cellular marrow at the upper ends of the diaphyses are practically free from bony trabeculæ.

The small bones of the hands and feet have not been examined sufficiently frequently to enable me to describe the changes in detail, but it is certain that conversion into fat is complete in them at an earlier age than is the case even in the radius and ulna, etc.

Summary of the Distribution of the Red Marrow in the Adult.—In the adult the vertebræ, sternum, ossa innominata and the greater part of each rib contain red cellular marrow.

The only red marrow in the long bones of the limbs is found in a small area at the upper ends of the diaphyses. Longitudinal section of the long bones gives an incorrect picture of the exact distribution of the red marrow, whereas transverse section demonstrates that the fatty tissue is mainly confined to the axis of the medullary cavity, while the periphery still contains some cellular marrow for a varying distance below the lower edge of the definite mass of red marrow which is so well seen on longitudinal section.

Changes in the Distribution of the Red Marrow in the Adult.—When one bears in mind the hæmatopoietic function of the bone-marrow in post-natal life, as demonstrated by Bizzozero[2] and Neumann,[3] it is obvious that any condition of the body which demands an increased supply of blood-cells, either red or white, will throw a large amount of extra work on the hæmatopoietic depôts. If such a demand be comparatively slight or of short duration, the existing tissue will suffice to produce the cells required: this is seen in the ordinary process of digestive leucocytosis. If, however, the demand is intense and long continued, it will be necessary for the cellular marrow to hypertrophy in order to supply an adequate number of cells to the circulation. Such hypertrophy is seen in

leukæmia, pernicious anæmia, and many other conditions. It is, therefore, correct to state that the red marrow can increase in amount even in adult life in response to many varieties of stimuli.

III. THE BLOOD-VESSELS OF THE BONE-MARROW.

The gross anatomy of the blood-vessels of the bone-marrow is well known, but apparently the extreme importance of a comprehension of the finer anatomy has escaped general notice. The best method of demonstrating the distribution of the blood-vessels in the marrow is by means of specimens which have been injected with a carmine-gelatin mass; but even ordinary microscopic sections, stained with eosin, show the distribution of the blood channels quite distinctly. In the fatty marrow the blood channels are ordinary well-formed vessels, but as soon as the red marrow is reached the conditions become much more difficult to follow. The red marrow is essentially a tissue consisting of innumerable blood channels with extremely thin walls. Outside these channels are hæmatopoietic cells. *Fig.* 176 shows the arrangement of the blood-vessels in the red marrow. It is obvious that the great widening of the stream-bed of the blood at the junction of the fatty with the red marrow must involve a great decrease in the rate of flow in this area. It is important to recollect that the veins in the medullary cavity possess no valves, although it would appear that those just outside the cavity possess more than the number usual in other vessels of the same size elsewhere. The anatomy of the vessels and lymphatics of the marrow was described in some detail by Schwalbe.[4]

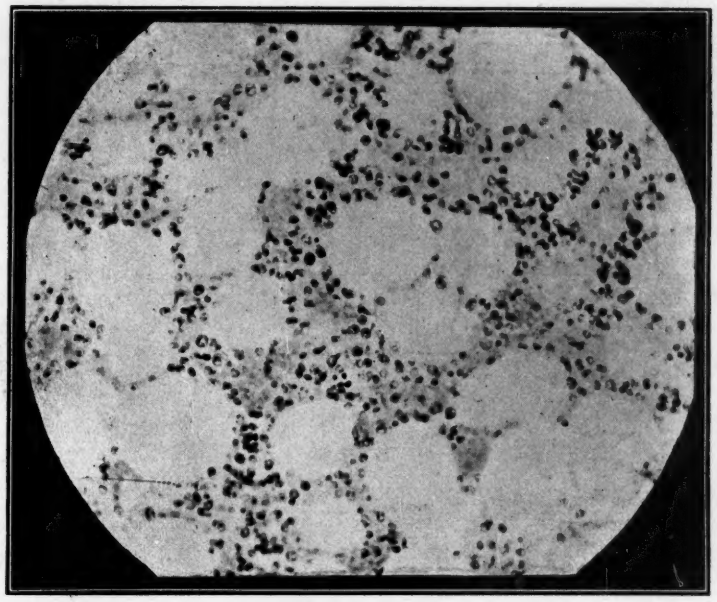

FIG. 176.—The pale areas in this figure represent the blood channels of the marrow: the white areas correspond to fat, while the dark elements are the marrow cells. This section was obtained from the marrow of the femur of a man, age 49. The extreme vascularity and the complicated arrangement of the course of the blood channels is well seen. (× 100.)

IV. LYMPHATIC CHANNELS IN THE BONE-MARROW.

It has been frequently stated that the bone-marrow contains no lymphatic channels, but I have been unable to find any reference to experiments relating to this matter. Ziegler[5] and Roger and Josué[6] state that there are no lymphatics in the marrow, but give no reasons for making this statement. The extremely careful work of Sampson Handley on the subject of lymphatic permeation has made it imperative to attempt to settle the matter. Dewey and Noyes[7] have used a very fine technique for the demonstration of lymphatic channels in teeth, and I have made use of this with slight modifications to make it applicable to such large objects as bones. The material used for injection was Prussian blue ground up with ether and turpentine in a mortar. I have found that it is possible to inject the lymphatic channels in the periosteum with comparatively little difficulty: the injection material passes from these channels into the bone and from it

into the endosteum, but I have been quite unable to find any evidence of a connection between these periosteo-endosteal lymphatics and the marrow tissue. If an injection is made with the modified Dewey-Noyes cannula directly into the marrow tissue by screwing the cannula into the compact bone, the injection material passes into definite channels in the marrow tissue. The difficulty of regarding these as lymphatic channels was the fact that the injection material emerged from the veins at the large foramina.

The next step in the investigation of these channels was an attempt at a double injection, i.e., of both blood-vessels and lymphatics in the same specimen. The method adopted was as follows: The blood-vessels were injected with a carmine-gelatin mass, and when this mass had been completely solidified by cooling in iced water, an attempt was made to inject lymphatic channels through the Dewey-Noyes cannula. Even if considerable force was employed in the attempt to fill lymphatic channels, the Prussian-blue-ether-turpentine mixture could not be made to move along the marrow tissue. The necessary conclusion was that the channels, which were filled with the blue suspension in the previous experiment, were only blood-vessels. It appeared possible that a few lymphatics might enter the long bones along the tendons of attachment of the great muscles, but no communications could be detected between their fascial lymphatics and the marrow tissue.

In conclusion, the only statement possible at the present time is that modern methods of injection do not demonstrate the existence of any structures in the bone-marrow which resemble lymphatics in structure or distribution. The writer well realizes that negative evidence of this character is not necessarily of value, but the absence of lymphatic channels from the marrow is only a minor portion of the evidence upon which the present paper rests.

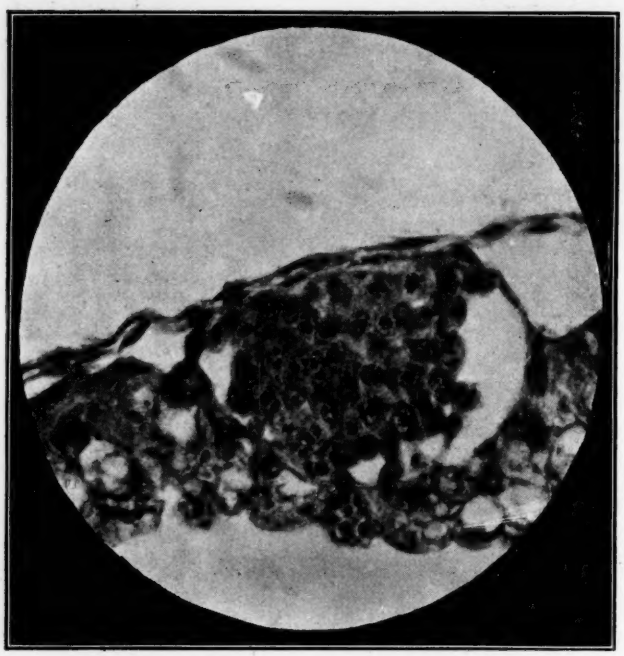

FIG. 177.—This figure shows one blood island from the wall of the yolk-sac of the embryonic canary. The clear portion in the upper part of the photograph represents the extra-embryonic cavity. The circumscribed cellular mass is the blood island which is surrounded by the primitive endothelium of the vessel, while the red cells are in process of differentiation in the interior. The cells around the blood island belong to the yolk-sac. (× 150.)

V. DEVELOPMENT OF THE BLOOD-FORMING TISSUES.

For the purposes of the present discussion there is little advantage in giving the well-known details of the development of the blood in the embryo, but although no thorough consideration is necessary, it is essential to refer to a few of the finer details of the histogenesis of the blood-cells.

There appears to be little doubt that Weidenreich[8] was perfectly correct in his contention that the white cells of the blood are not primarily true blood-cells, but are really specialized developments of the primitive amœbocytes, that is, cells formed in the primitive body cavity and only secondarily invariable components of the blood picture. When the development of the erythrocytes is considered, a very different arrangement is obvious. *Figs.* 177 and 178 show blood islands on the wall of the yolk-sac of the canary embryo and the human embryo respectively. It will be noted that the development of the red cells is an entirely intravascular process. Dantschakoff[9] and

other observers have noted that the process of erythropoiesis in birds is purely intravascular, while leucopoiesis is extravascular.

The reason for this peculiar arrangement will be obvious from the description of the different mode of the origin of these two types of cells. The conception of two types of hæmatopoiesis does not involve the conception of two ancestral cells for the two types of blood-cells; the lining cells of the marrow produce red cells on the side towards the lumen, while white cells are produced on the other side. In this way an explanation of the ordinary hyperplasia of the red marrow is available: under no conditions does one find a spread of the leucoblastic tissue without a contemporaneous spread of the erythroblastic: the converse is also true. Similarly, no injury to one process can leave the other completely intact. The present writer has dealt with this subject more fully in a paper read to the Pathological Society, in July, 1922, with W. T. Hillier.

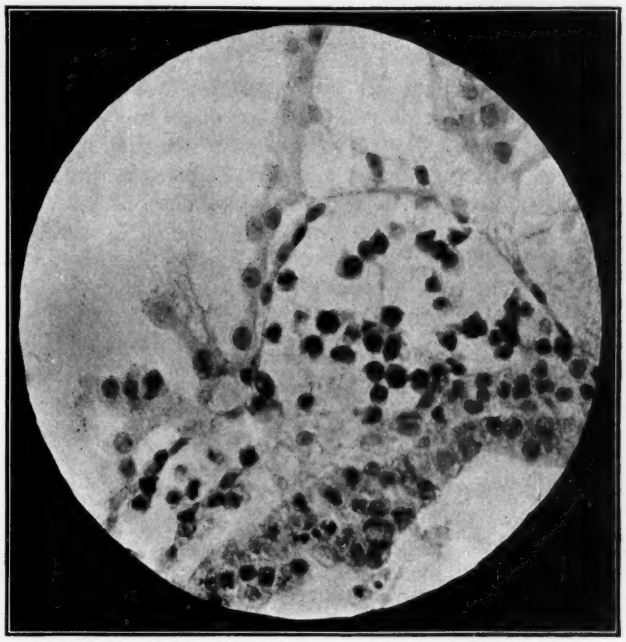

FIG. 178.—This figure shows similar appearances to those depicted in the previous one, but this specimen was obtained from a human embryo. (× 150.)

VI. THE CHARACTERS OF THE BLOOD PICTURE IN CASES OF CARCINOSIS OF THE BONE-MARROW.

The realization of the hæmatopoietic function of the adult bone-marrow was soon followed by a partial comprehension of the grave alterations in the character of the blood picture which were observed to follow the presence of metastases in the marrow. The blood picture in such cases was found to resemble that of 'pernicious anæmia' in many particulars, and in fact the first description of such a case by Ehrlich[10] was that of pernicious anæmia with incidental formation of a sarcoma.

The literature of hæmatology now contains details of many cases of this description, and it would appear that the alterations in the blood picture are independent of the site of the primary growth, and are only related to the presence of metastases in the marrow. Alterations of this 'pseudo-pernicious' type have been described in cases where the primary growth was in the stomach by Schleip,[11] Parmentier and Chabrol,[12] Harrington and Teacher,[13] and Harrington and Kennedy;[14] in cases of cancer of the breast by Epstein,[15] Houston[16]; and a case reported by G. R. Ward[17] was almost certainly of the same character, although no confirmation was possible, as an autopsy was not permitted. Grawitz[18] reported a case of this type in which the primary growth appears to have been in the suprarenal gland; Reichmann[19] described a case with similar alterations in the blood picture and a primary growth in the œsophagus; Schleip[11] gives details of such a case where the primary tumour was a colloid cancer of the appendix, and also reported another where the primary focus was in the jaw. There are doubtless other cases recorded in the literature, but I think that sufficient evidence has been presented to make it clear that there is no close relation between the site of the primary tumour and the character of the blood change.

It must be borne in mind that almost every case of cancer shows a definite degree of anæmia, but this is not of a specific character. Although the ordinary anæmia of cancer is not dependent upon the presence of metastases in the bone-marrow, it is dependent upon changes in that organ. The chronic anæmia of protracted cases of cancer leads to an increase in the amount of red cellular marrow in the bones.

It would appear from the work of McMaster and his collaborators[20] that hæmoglobin or one of its decomposition products is the essential stimulus to increased hæmatopoiesis after destruction of red corpuscles in the body. The cases of cancer in which the liver does not give a 'free iron' reaction are very rare, and are always those in which there is little or no increase in the amount of red marrow in the bones.

This increase in the amount of the red marrow is of great importance in connection with the present subject, as I propose to demonstrate that the red marrow is the site of deposition of cancer in bones. A brief description of the alterations in the character of the blood picture in these cases is necessary, because they are not usually quite easy to interpret, and also because some recent writers appear to be unaware of them, and thus are led to publish misleading interpretations of a blood picture. In a recent controversy arising out of a paper by Izod Bennett and Dodds[21] on the nature of the achlorhydria of pernicious anæmia, there has been an example of this misinterpretation. Dr. A. E. Hurst[22] suggested that the development of 'pernicious anæmia' in four cases of carcinoma of the stomach after total gastrectomy was evidence of the primary character of the achlorhydria of pernicious anæmia. Unfortunately, no detailed account of the blood picture was published, and therefore no definite statements can be made, but when one notes the great similarity between the condition of the blood in cases of carcinosis of the marrow and in pernicious anæmia, one would be chary of accepting the evidence of the true 'pernicious' character of these cases.

In this section I shall consider some of the cases of this type which have been published during the last fifteen years. One of the most carefully described cases with which I am acquainted is that published by Harrington and Teacher.[13] The patient was a woman, age 64, who suffered from vague pains in different parts of the body ; the most noticeable abnormality which was detected was a very definite anæmia ; melæna was frequent. The authors report several blood-counts, of which the following is a typical example :—

Red corpuscles	1,600,000 per c.mm.
Hæmoglobin	35 per cent.
Colour index	1·09
Leucocytes	14,000 per c.mm.

A differential count of the leucocytes gave the following result :—

Neutrophil polymorphonuclear cells ..	63·00	per cent.
Eosinophil ,, ,, ..	0·70	,,
Basophil ,, ,, ..	0·00	,,
Lymphocytes	16·70	,,
Large mononuclears and transitionals ..	18·80	,,
Myelocytes	0·80	,,

In counting 500 leucocytes they noted 29 megaloblasts and 4 normoblasts. The authors state that myeloblasts were present, but no figures are given.

Three weeks later the most marked change in the blood picture was a rise in the number of myelocytes up to 6 per cent of the total number of leucocytes. Polychromatophilia and punctate basophilia were well shown, but there was only slight poikilocytosis, while megalocytosis was very marked.

In this case the autopsy showed that they had been dealing with a case of scirrhous cancer of the stomach with numerous metastases in the ribs, vertebræ and femur.

Harrington and Kennedy[14] reported a similar case in which the total number of leucocytes per cubic millimetre was 10,000 and the primary tumour was in the stomach. The leucocytes were present in proportions somewhat similar to those in the first case; thus there were 2 per cent of myeloblasts, while the myelocytes formed 0·5 per cent of the total number of leucocytes. The colour index was above 1.

Parmentier and Chabrol[12] reported a similar case in which the primary tumour was also in the stomach. Only one blood-count was performed just before death, and, although there was a very definite anæmia with a high colour index, there were only 3500 leucocytes per cubic millimetre.

Schleip[11] has reported blood changes of this type in three cases, in which the primary tumours were in the stomach, appendix, and jaw respectively.

Houston's case[16] of carcinoma of the breast with metastases in the bones showed a colour index of 1·28.

Reichmann's case of carcinoma of the œsophagus[19] showed a colour index of only 0·66, but the blood picture was of the same character in other respects.

No good purpose would be served by referring in detail to the large number of other cases which can be found in the literature. It may perhaps be serviceable to give a summary of the changes of the constitution of the blood picture which can be regarded as sufficiently characteristic for the diagnosis of carcinosis of the bone-marrow to be made during life.

Carcinosis of the Marrow.	'Pernicious Anæmia'.
1. Reduction in the number of red corpuscles.	1. Similar reduction.
2. High colour index, not always above 1.	2. Colour index usually above 1.
3. Slight leucocytosis.	3. Usually slight leucopenia.
4. Leucocytosis due to increase of neutrophil polymorphs.	4. Relative lymphocytosis.
5. Anisocytosis, etc., well marked.	5. Similar appearances.
6. Nucleated red corpuscles present, both normoblasts and megaloblasts.	6. Always present, but vary in number at different times.
7. Myelocytes and myeloblasts present.	7. Myelocytes are not uncommon, myeloblasts are rare.

It will be obvious that the essential feature of the blood picture in these cases of carcinosis of the bone-marrow is the evidence of a grave disturbance of the erythropoietic organs while, in addition, there appears to be some interference of a stimulating nature acting on the leucopoietic mechanism.

At this point it might be instructive to refer to a different type of case which I had an opportunity of examining both before and after death.

The patient was a man, age 40, with well-developed Hodgkin's disease. Examination of his blood revealed the following surprising picture :—

Red corpuscles	..	4,650,000 per c.mm.
Hæmoglobin	..	90 per cent
Leucocytes	..	45,000 per c.mm.

A differential count of the leucocytes revealed the following proportions :—

Neutrophil polymorphonuclear cells			75	per cent
Neutrophil myelocytes	..	..	4	,,
Myeloblasts	..	..	15	,,
Lymphocytes	..	..	6	,,

A second count a week later showed little change in the blood picture. In this case the blood shows no evidence of any interference in the process of erythropoiesis, but there is evidently much alteration in the mechanism of leucopoiesis.

I am able to find only two cases of secondary carcinosis of the marrow in the literature in which the blood picture was of this extraordinary character. The first case was that of Dieballa and Entz,[23] in which the leucocytes reached the surprising number of 112,600 per c.mm., and it is stated that there was no myeloid metaplasia in the liver and spleen. The second case was that of Bizarri,[24] in which there appears to have been a definite leukæmia of the myelogenous type with the well-known anatomical changes in the liver and spleen, in addition to a cancer of the stomach. The second case is of little importance in the present discussion, but the first presents some difficulty. Dieballa and Entz stated that both the liver and the spleen were enormously enlarged in their case,

and, as they offer no explanation of this phenomenon, it seems fair to leave their case out of consideration, and it has only been included in order to give completeness to the account of the varieties of blood change which have been known to be associated with cancer in bone-marrow.

Blood changes of the 'pseudo-pernicious' type have aroused considerable interest, mainly from the point of view of diagnosis, but it appears to me that there is another and wider interest, as affording evidence of the mode of spread of cancer into the medulla of bones. In the section which deals with the development of the blood-forming tissues, I have pointed out that erythropoiesis is an intravascular process, while leucopoiesis is extravascular. If the very equivocal case of Dieballa and Entz be disregarded, it will be noted that the essential change in the blood picture in cases of carcinosis of the marrow is a grave disorder of the distribution and appearances of the red corpuscles in the circulation, while the leucocytes show a far less intense degree of change.

It is usually admitted that lymphadenoma (Hodgkin's disease) is of the nature of a chronic granulomatosis rather than neoplastic in character. The mode of infection is quite unknown, and even the means by which deposits in foci distant from the primary granuloma develop is uncertain. There is no evidence pointing to a transfer of cells in these cases from one organ to another. Occasionally it is possible to see the lymphadenomatous process invading the walls of veins, but there is no evidence that cells capable of growth elsewhere are disseminated in this manner. Although the unknown virus of this disease may be carried in the blood-stream, there are no histological appearances which would lead one to suppose that the granulomatous tissue develops primarily in the blood-vessels. As all the evidence shows that lymphadenoma is an extravascular process, it is not surprising that deposits of this granuloma in the bone-marrow lead to alterations in the distribution of the circulating leucocytes. The case which is partly described above showed large masses of lymphadenomatous tissue in the marrow of many of the bones, and these were regarded as the cause of the strange blood picture which had been noted during life.

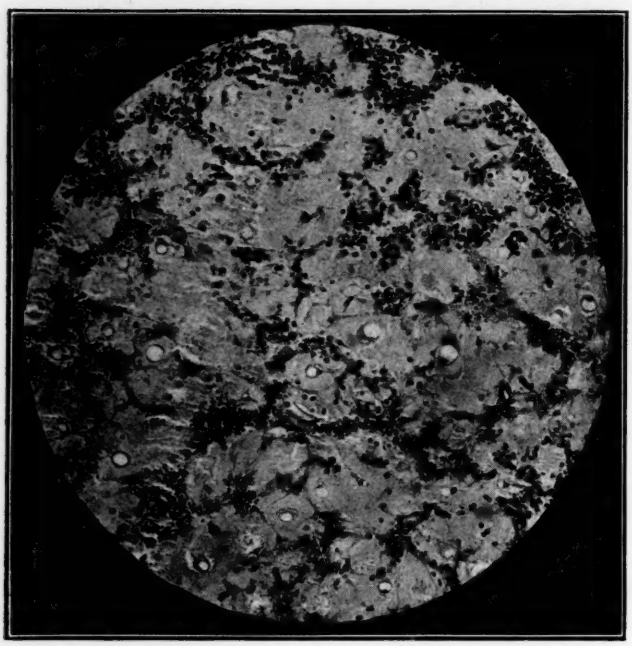

FIG. 179.—*Case* 4. This shows the appearance of advanced gelatinous degeneration of the marrow. It will be noted that in the degenerated areas there are no marrow cells, and a lack of evidence of marrow reaction in a case of this description is not surprising. (× 100.)

This case is, therefore, an example of the effect of an extra-vascular lesion in the bone-marrow. It would appear perfectly justifiable to presume that the changes in the number and distribution of the red corpuscles in cases of carcinosis of the marrow are due to intravascular lesion.

At this point it must be admitted that cases of carcinosis of the marrow are on record in which there was no pseudo-pernicious blood picture. Middleton[25] has published such a case, where the primary growth was in the stomach. He remarked on the absence of reaction in the marrow tissue. Even if one cannot admit the existence of idiopathic cases of marrow aplasia in these malignant conditions, it is possible to conjecture as to the cause of the absence of the peculiar blood conditions. *Fig.* 179 shows a portion of bone-marrow from a case

of carcinosis of the marrow (*Case* 4) in which no blood changes other than those of simple anæmia were detected during life. The photograph shows a very advanced stage of 'gelatinous' degeneration of the marrow. It would be surprising if so degenerate a tissue could show much sign of reaction to any form of lesion. If metastases of cancer settled in the bone-marrow at an early stage of the life-history of the primary growth, one would not expect that blood changes would be very well marked, because of the absence of hyperplasia, due to lack of previous anæmia.

A third cause of the absence of pseudo-pernicious changes would be great extension of the cancerous process, and extreme destruction of the marrow tissue. G. R. Ward[17] made an interesting and important observation which bears a relation to this portion of my argument: in a case of aneurysm of the aorta, which was pressing upon and eroding the vertebræ, the blood was found to present no deviation from normal. It appears certain that the effect of deposits of cancer in the bone-marrow is specific, and there are apparently insuperable difficulties about any explanation of the blood changes if the conception of an intravascular trauma is not accepted.

In all the cases in which pseudo-pernicious blood changes have been recorded in the literature, there has been a remark on the extremely dense fibrous character of the primary growth, i.e., these have been cases in which the disease has been present for a sufficiently long time to permit hyperplasia of the marrow to have taken place.

VII. THE MODE OF SPREAD OF CARCINOMA INTO MARROW.

It is not the purpose of this paper to deal with those cancers of bone which are due to extension from a primary growth directly into the neighbouring bones; only such tumours as are ordinarily regarded as metastatic will be considered.

The old conception of a 'cancerous diathesis' is not discussed in detail: the only modes of spread which fall to be considered are dissemination by the blood-stream and permeation of the lymphatics. Before dealing with the literature of the subject, I will give a brief account of the cases which I have had an opportunity of examining.

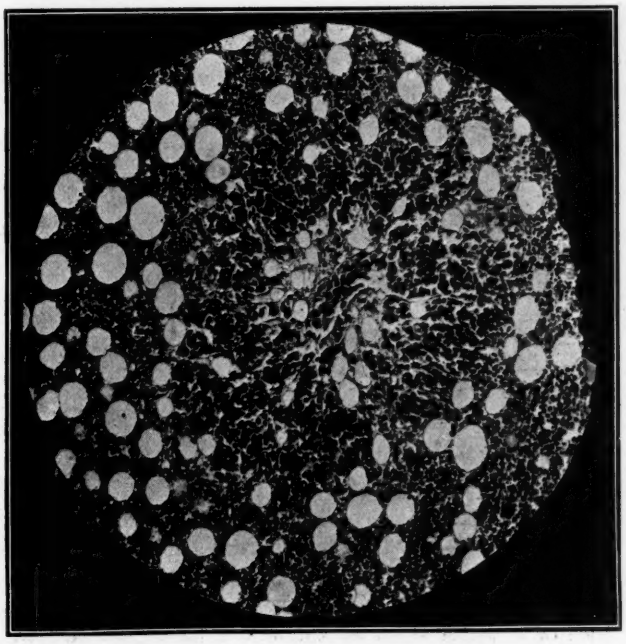

FIG. 180.—*Case* 1. This figure shows the appearance of one of the smaller masses of metastatic tumour in the marrow of the femur. The fungus-like mass of cells lies in the midst of hyperplastic cellular marrow, and, in the centre of the mass, the cells are seen to be arranged in a straight line. (× 100.)

Case 1. — This patient was a woman, age 55, who was admitted to hospital with an ulcerated and discharging nipple. She stated that the condition was of two years' duration.

On examination, the left nipple was found to have been destroyed by ulceration, and a few hard glands could be palpated in the left axilla. The left breast was amputated and the axilla was cleared. Two months later the patient, who appeared to be well, was sent to a convalescent home, where she died within a month. The autopsy was performed on May 25, 1920, about twenty-four hours after death, and an abstract of the notes is given here.

The body was that of a stout woman showing early signs of wasting. There was a number of minute tumours on the pleuræ, but the lungs appeared to be free from invasion. The liver, which weighed 2700 grm., was extensively invaded by metastatic deposits which appeared to bear a close relationship to the

portal tracts. A few retroperitoneal glands showed signs of early invasion. The ribs were extensively invaded by nodules of tumour, which, in places, filled the whole medullary cavity, but did not penetrate the bone, and the periosteum was not affected. The vertebræ were extensively invaded, and the metastases had produced softening in the affected bones.

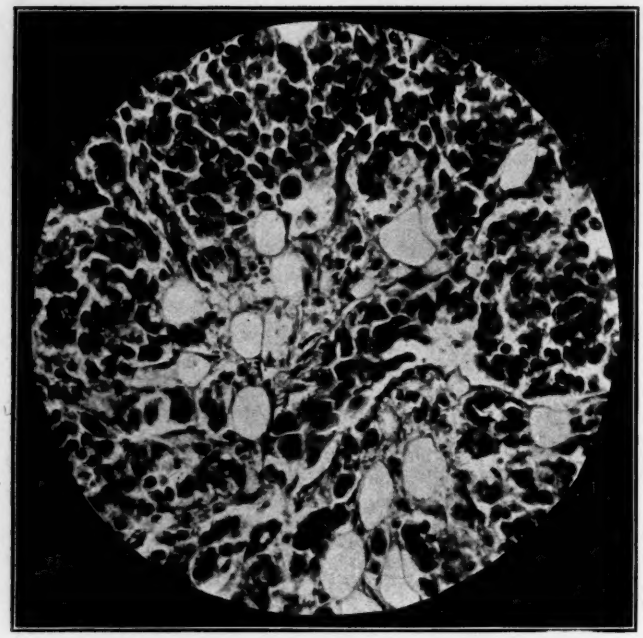

FIG. 181.—*Case* 1. This figure shows the central portion of the small tumour which is seen in the previous illustration. The row of cells in the centre is seen to be lying in a definite channel, which is lined by endothelium. It will be noted that in neither of these figures is there any appearance of blood channels other than the one containing the cancer cells. (× 200.)

The right femur was cut longitudinally and the cut section appeared red almost down to the lower end, but in this red tissue there were about a dozen white areas; the largest of these white areas were in the upper third of the medullary cavity, while the smallest were in the lowest part of the red tissue. The upper epiphysis contained red tissue and also tumour nodules, but the lower epiphysis was mainly fatty and was free from tumours. The bony trabeculæ were almost indetectable in the red tissue of the shaft.

On microscopical examination, the primary growth was found to be a scirrhous carcinoma, and the deposits in the liver were of a similar character, although many of the nodules showed marked necrotic change. The metastases in the bones were of a more cellular character than the primary growth, and, in the case of the smaller growths, resembled small radiating fungi in the surrounding hyperplastic marrow tissue (*Fig.* 180). With higher magnification it was possible to see quite clearly that the tumour cells in the centre of such a mass lay in a definite channel, which was lined by endothelium, and there was no reason for supposing that this was not a blood-vessel (*Fig.* 181).

I have to thank Mr. Seymour Barling for permission to refer to the above case, which was under his charge.

Case 2.—The patient was a man, age 46, who was diagnosed on clinical evidence as suffering from carcinoma of a bronchus with secondary deposits in the liver.

The autopsy revealed the presence of a white mass of tumour at the root of the left lung: this invaded the lung tissue and appeared to arise from a bronchus. There were many metastases in the liver, which weighed 2500 grm. Both suprarenal glands were invaded by nodular tumour growth. The sixth rib on the left side was invaded by tumour which had perforated the periosteum on the pleural aspect, but had not invaded the pleura. The right femur

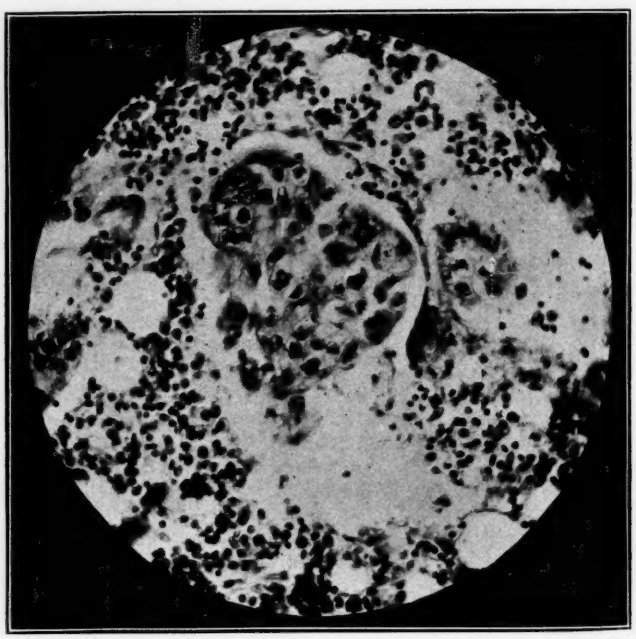

FIG. 182.—*Case* 2. This figure shows a single mass of metastatic tumour in the marrow of the humerus. The circumscribed mass is seen to lie in a definite channel, and no blood-vessels are seen in the neighbourhood. (×100.)

showed a small mass of tumour tissue in the periosteum at the junction of the upper third with the lower two-thirds of the bone; a needle could be pushed into this nodule for a distance of about an inch. On cutting the bone longitudinally, this small mass in the periosteum was found to correspond to a large white area of metastatic deposit in the medullary cavity. The red marrow had extended about half-way down the medullary cavity, but no other metastases were found in it. The left humerus, on section, showed the presence of a white nodule at the junction of the upper third with the lower two-thirds of the bone, but no invasion of the periosteum could be found.

On microscopical examination, the bronchial tumour was found to be a cellular carcinoma of glandular type. The nodules in the bones were of similar structure, and it was easy to find plugs of tumour cells lying in channels, which were lined by endothelium. The periosteal mass at the upper end of the femur did not show any signs of intravascular arrangement and was continuous with the tumour in the medullary cavity through the eroded compact bone. The appearances of the metastatic deposits in the humerus can be seen in *Fig.* 182.

I have to thank Professor J. W. Russell for permission to refer to this case, which was under his charge.

Case 3.—The patient was a man, age 55, admitted to hospital with an acute abdominal catastrophe. At operation a perforation of a stercoral ulcer in the cæcum was found.

The autopsy showed that death was due to general peritonitis following perforation of a stercoral ulcer in the cæcum in a man suffering from carcinoma recti.

No metastases could be found in any of the organs, including the bones. The only long bone which was examined was the right femur, and in this the red marrow was found to occupy the upper third of the medullary cavity, the remainder of that space being filled with fat.

On microscopical examination, the primary tumour in the rectum was found to be an adenocarcinoma. Sections from the red marrow at the upper end of the right femur showed the presence of emboli consisting of tumour cells in the blood-vessels. The tumour cells lay in vessels which had a definite endothelial lining and contained red blood-corpuscles in a good state of preservation (*Figs.* 183 and 184).

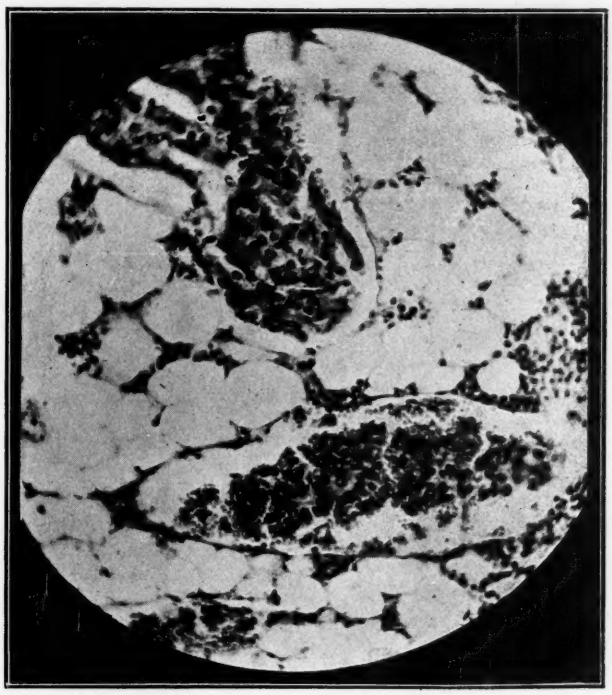

FIG. 183.—*Case* 3. Shows the intravascular arrangement of the cancer cells in the marrow. In the vessel in the lower part of the field there are epithelial cells in the middle of the lumen, while the periphery is occupied by red blood-corpuscles. It will be noticed that there is practically no appearance of reaction on the part of the marrow tissue, and this is compatible with the fact that these metastases were of extremely early date in the history of this case. (× 100.)

I have to thank Mr. J. B. Leather for permission to refer to this case, which was under his charge.

Case 4.—The patient was a woman, age 23, who had enjoyed good health until about six weeks before her death, when she noticed pain in the lower part of the back and the development of lumps in the neck. The blood was only examined on one occasion about four days before death and no marked deviation from the normal condition could be detected other than a slight decrease in the number of red corpuscles, which were calculated at 4,000,000 per cubic millimetre.

The post-mortem examination showed the presence of a tumour in the right lung. The upper lobe of this lung was white in colour and firm in consistence, being completely converted into tumour, which invaded a bronchus. The lower lobes contained only a few discrete masses of tumour. Metastases were found in the bronchial glands, left suprarenal gland, and left ovary. There were thread-like lymphatics all over the surface of the heart, and these were found to be filled with tumour cells.

The bones were examined as far as was possible and extensive invasion was found. All the segments of the vertebral column were invaded in varying degrees, as were also most of the ribs. The sixth rib on the right side was almost fractured by growth, but, on the inner aspect, the

compact bone still remained and separated the growth from the pleural periosteum. The tumour in this rib lay about one inch behind the costochondral junction.

The left clavicle showed a condition of almost complete fracture, but the posterior lamella of compact bone was not completely eroded. There were tumours in both humeri: in each case these were situated at the junction of the upper third with the lower two-thirds of the bone—the position of the red marrow normally present at this place in the adult. The red marrow in this case occupied an area which was no larger than that normal in persons of this age. The compact bone surrounding the medullary cavity was not eroded. In the head of the right humerus there was a nodule of tumour lying in the cancellous bone.

On transverse section of a bone at a point corresponding to a metastasis, it could be seen that the tumour mass lay completely in the marrow and did not invade the compact bone, although it lay in contact with it at the inner side of the cavity. The right femur was examined and showed a tumour lying in the red marrow at the upper part of the medullary cavity. No tumours could be found in the medullary cavity or epiphyses of the right tibia, which contained fatty tissue and no appreciable amount of cellular marrow. A nodule of cancer was present in the substance of the musculus tibialis anticus, and this was in contact with the tibia.

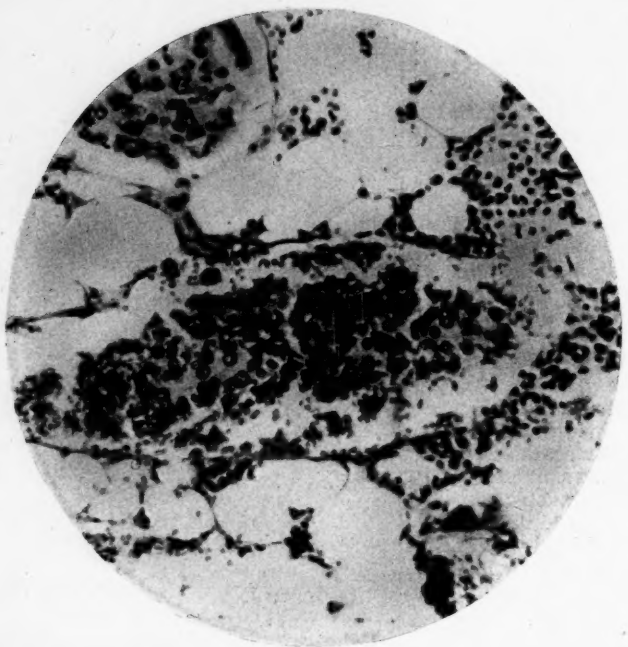

FIG. 184.—*Case* 3.

On microscopical examination, the primary tumour in the lung was found to be a carcinoma, apparently derived from the epithelium of the alveoli, and the metastases in other organs showed very great similarity in structure; this similarity was most marked in the case of deposits in the vertebral column (*Fig.* 185). The metastases in the long bones showed an alveolar arrangement, but this was not quite so similar to the primary tumour as were the deposits in the vertebral column. The nodules in this case were more advanced than those in the previous cases, and it was not easy to find a plug of cells lying in a vessel; but ultimately a mass of cells was found lying in a definite channel, which was lined by endothelium (*Figs.* 186 and 187).

The marrow tissue in this case was scarcely hyperplastic, but there was definite 'gelatinous degeneration' visible in some places (*Fig.* 179). This case illustrates the point that metastases in bone lie in the red cellular marrow and do not extend into the fat. There is no evidence in this case that the metastases had extended into the medullary cavity from the periosteum. The nodule which lay in the musculus tibialis anticus was only adherent to the tibial periosteum, and no sign of invasion of the periosteal lymphatics could be found on microscopical examination. The tumour in the sixth rib shows the preference of metastatic deposits for the place at which fatty marrow passes over into the red cellular marrow.

I have to thank Professor J. W. Russell for permission to refer to this case, which was under his charge.

These four cases are quite illustrative of the morbid anatomical features of carcinosis of the bone-marrow. The main points worthy of attention are :—

1. The position of the cancer cells in channels which are lined by endothelium.

2. The escape of the distal bones of the limbs.

3. The absence of evidence of permeation of fascial lymphatics in the neighbourhood of the invaded bones.

4. The position of the metastases, which is always in the red cellular marrow.

5. The points of emergence of the tumour on the surface of the bones correspond to the places of exit of the veins.

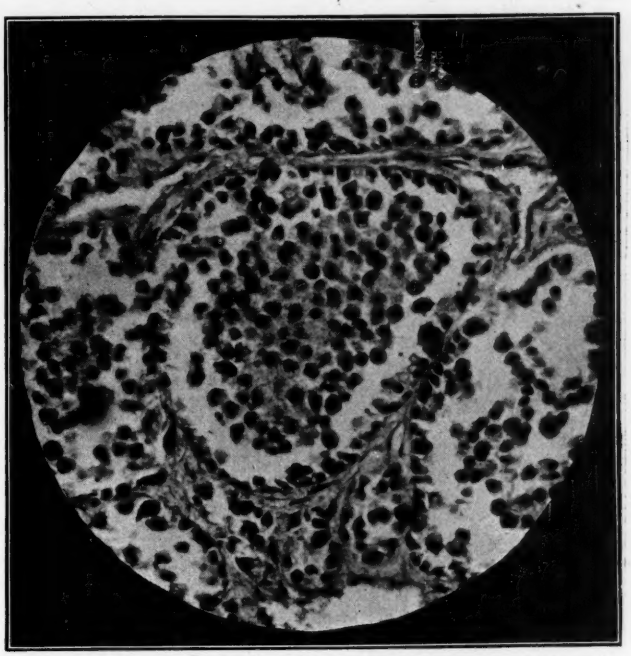

FIG. 185.—*Case* 4. Shows a portion of one of the many metastases in the vertebral column. The close resemblance of this secondary deposit to lung tissue is well seen. The masses in the vertebræ were so advanced as to make it impossible to discover any arrangement in vessels. (× 100.)

LITERATURE AND DISCUSSION.

F. von Recklinghausen[26] was the great exponent of the theory of the spread of metastases by the blood-stream into the marrow. His main contentions in favour of this conception were as follows :—

1. Metastases in bones occur in the interior of the medullary cavity, and only reach the periosteum by extension from this place.

2. The masses in the subperiosteal tissue are always in the region of the large foramina which serve for the outward passage of the veins.

3. The cancer cells in the marrow lie in definite channels which are arranged in a manner similar to that of the veins normally present in the marrow. He believed that these canals were blood channels for two reasons : (*a*) Because no lymphatics were known to exist in the marrow, and (*b*) because no other blood channels than the invaded ones could be found in the affected areas. He admits that he was unable to discover any place in which such a channel contained both cancer cells and red blood-corpuscles.

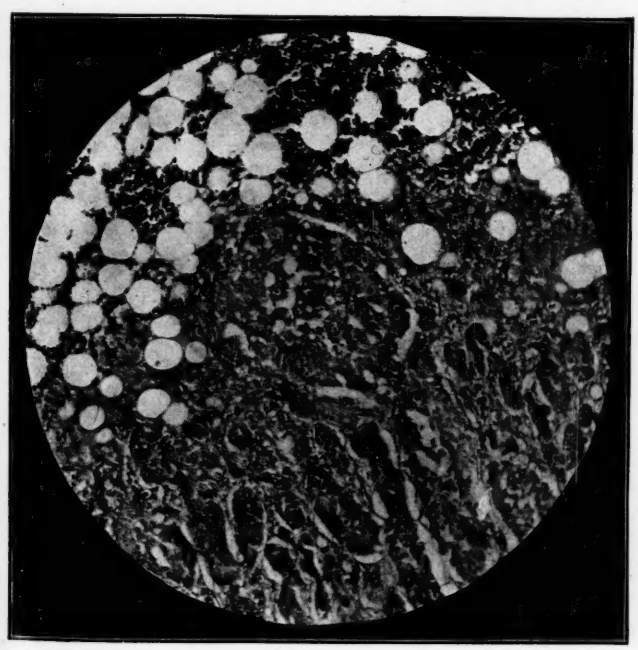

FIG. 186.—*Case* 4. The upper portion of the figure shows rather hyperplastic marrow tissue, while the lower two-thirds shows invasion by cancer. It will be noted that a mass of epithelial cells lies in a definite channel at the junction of the marrow tissue with the tumour mass. (× 100.)

In the marrow of one of his cases Assmann[27] was able to find a capillary which was blocked by cancer cells, while another branch of the same vessel was quite free from invasion and only contained red blood-corpuscles.

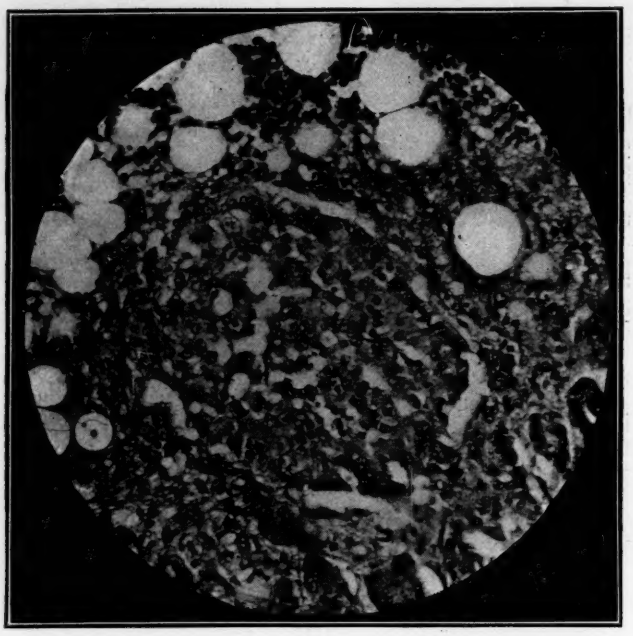

FIG. 187.—*Case* 4. Shows the arrangement inside the channel which is seen in the previous photograph. An appearance of degeneration can be seen in the marrow tissue at the edge of the tumour mass. (× 200.)

Erbslöh[28] was able to observe masses of epithelial cells in vessels, which still contained red corpuscles, in a case of carcinosis of the marrow secondary to carcinoma of the bile passages.

Goetsch[29] was inclined to believe that the subperiosteal nodules which occurred in some of his cases were earlier than those in the medullary cavity; but microscopical examination showed that the tumour in the marrow had undergone a greater degree of degeneration than had that in the periosteum, and was, therefore, probably the older. He was also able to observe that the cancer cells in the marrow lay in channels which occasionally were seen to contain red corpuscles.

It will be seen that the conception of dissemination by the blood-stream has appeared to many observers to be the almost certain explanation of the metastases in the bone-marrow; nevertheless, there is a school which holds that the invasion of bones is by means of lymphatic permeation. Sampson Handley, to whom the science of morbid anatomy owes its revival, is the great champion of the conception of lymphatic permeation as applied to the metastases in bones. His classical work on 'Cancer of the Breast'[30] has been the source from which I have obtained the details of the theory, which has done so much to advance the art of surgery in relation to the mammary gland; but, as far as it is applied to the invasion of bones, I am unable to accept it.

Many of Handley's statements are based on the most careful observation and are, therefore, quite immune from criticism; but the interpretations are liable to alteration. As far as I can gather the arguments from his work, they are as follows:—

1. The freedom of the distal bones of the limbs from invasion by secondary cancer is regarded as incompatible with the conception of embolic spread, because these bones would be quite as liable to embolism as any others.

2. The liability of a bone to cancerous metastasis is said to increase with its proximity to the primary growth.

3. The femur is said to be invaded at the base of the great trochanter, but fracture usually occurs somewhat lower down on account of the thinner compact bone; invasion and fracture of the humerus are said to occur about the middle of the bone.

4. He disposes of the argument that deposits bear a close relation to the direction of the nutrient artery by pointing out that, in the humerus, the deposits are above the point of entrance of the nutrient vessel, which is directed distally.

5. If the bones are invaded from the lymphatic plexus of the deep fascia, the point of attack should be the part of the bone which lies nearest to the cutaneous surface, and this, he says, is the case.

6. The escape of the distal bones is simply due to the fact that the patient usually

dies before the process of lymphatic permeation has proceeded sufficiently far to invade the deep fascia of the distal parts of the limbs.

7. As additional evidence of the conclusion that bone metastases are associated with lymphatic permeation, he points out that the areas liable to cutaneous nodules and to bone metastases are similar in extent. He has demonstrated that cutaneous nodules are certainly due to permeation of fascial lymphatics.

In a footnote he says, " I do not deny that in rare cases bone deposits may be the result of arterial or capillary embolism ".

It has seemed to me that the most satisfactory mode of criticism would be the consideration of each of these headings separately, so that a final summary of the evidence in favour of the theory of cancerous embolism as an efficient cause of carcinosis of bones might be appended to this paper.

1. The apparent immunity of the distal bones of the limbs is explicable on definite anatomical grounds. It will be recalled that, in the section of this paper which deals with the anatomy of the adult bone-marrow, it has been pointed out that the red marrow persists only in the upper ends of the shafts of the proximal bones of the limbs. It was also pointed out that the blood-supply of this cellular marrow was extremely complicated, inasmuch as the definite channels in the fatty tissue break up into a vascular system which is not unlike an angioma in arrangement. It is obvious that this widening of the stream-bed must be associated with a very considerable decrease in the rate of the blood flow. Decrease of the rate of blood flow is always associated with 'pavementing' of the leucocytes, which are the solid bodies of the normal circulation. There appears to be no adequate reason for supposing that cancer cells would not be cast out to the periphery of the stream in a similar manner. In normal circumstances there is no evidence that leucocytes divide in the course of their journey in the main circulation, but in the red marrow they can often be seen lying in the periphery of the blood channels and showing evidence of division. These facts indicate that the stream at the periphery of the marrow vessels is slow, and that the development of cells in this situation would not be interfered with in a marked manner.

The process of embolism demands both the presence of insoluble particles in the circulation and also the possession of a suitable site of lodgement for such particles. The slowness of the circulation and the complication of the course of the marrow vessels appear quite adequate to supply the second factor.

All these points are a portion of the explanation of the fact that metastases in the bone-marrow invariably lie in the cellular marrow and never in the fatty tissue.

2. If there is a greater liability to invasion on the part of the bones nearest to the primary growth, it may be due to direct invasion of the arterial system in the region, but my own observations and my investigations of the literature have not shown that there is any such predisposition.

3. Handley states that the femur is invaded at the base of the great trochanter but that spontaneous fractures occur rather lower down on account of the thinner layer of compact bone. The site of invasion corresponds to the area of red marrow in the normal adult femur. He states that the humerus is invaded about the middle of the shaft and also breaks in this position : he gives no reason for ignoring the possibility of invasion rather higher up, with subsequent spread in the distal direction. My cases show that the first invasion is at the upper end of the diaphysis and that dissemination can occur both upwards and downwards. Metastases in the medullary cavity are always situated in the red marrow, and growth along the cavity is associated with an increase in amount of the red marrow which always precedes the deposition of the metastases.

4. The arguments of Handley efficiently dispose of the idea that the direction of the nutrient artery is of any importance in this connection.

5. The position of metastases at the periphery of the medullary cavity is explicable on the basis of the embolic theory, because of the lower level to which the cellular marrow reaches at the periphery : this is described in some detail in the section which deals with the anatomy of the organ.

6. The discussion of this contention was dealt with in paragraph 1 above.

7. The resemblance in extent between the areas liable to cutaneous nodules and those liable to metastases in the bones is surely a very weak support for Handley's contention. Many cases with cutaneous nodules in an advanced state of development show no signs of invasion of the bones, and most certainly not all cases of carcinosis of the bones are accompanied by cutaneous nodules.

There are several other points which merit attention. Thus, there may be difficulty in the explanation of the spread of cancer cells in the circulation from the venous side to the arterial side without involvement of the lungs. M. B. Schmidt[31] showed that small thrombi containing cancer cells were common in the capillaries of the lungs even in cases where there was no tumour in these organs on ordinary examination. Many of the epithelial cells in such thrombi appear to be destroyed; but he was able to observe that they might, on occasion, grow through the thrombus material; in this way cells may easily pass through the lesser circulation and be set free in the greater circulation and so pass to the bones.

If bones were invaded by permeation of lymphatic channels, it would be reasonable to suppose that examination of the periosteum would show evidence of invasion before the medulla contained any epithelial cells. In *Case* 2, where the periosteum of the femur was invaded, there was no evidence that the cells lay in any channels in this tissue, and in addition the periosteal tumour was in direct continuity with the cancerous mass in the medullary cavity. This bone is obviously one from which it is impossible to draw any definite conclusions, but the other bones in this case were found to contain tumour in the medullary cavity and not in the periosteum, and in their case it seemed impossible to conceive that invasion was from the periosteal lymphatics. In *Case* 4, the nodule which affected the periosteum of the tibia was a direct extension from the mass in the musculus tibialis anticus, and the lymphatic channels in the adjacent periosteum were unaffected.

In addition to the cases which I have had the opportunity of examining, there are many published cases which bear out my contention that the site of first settlement of metastases in bones is in the medullary cavity: in fact I have been unable to find any published cases, other than those of Sampson Handley, in which careful examination had led the author to any other conclusion.

VIII. THE EVIDENCES OF THE EMBOLIC ORIGIN OF METASTASES IN THE MARROW.

1. The absence of any histological or experimental evidence of the presence of lymphatic channels in the bone-marrow is an important argument in favour of the contention that carcinomatous metastases reach the bones by means of the blood-stream. It is admitted that the proof of a negative proposition of this kind is always an extremely uncertain basis of argument, but in the present case there are so many even more important evidences of the embolic theory that this one need not be unduly stressed.

2. The demonstration of plugs of epithelial cells in channels lined by endothelial cells and surrounded by red corpuscles in *Case* 3 is evidence in favour of the embolic theory which is very difficult to confute. In other cases it has not been possible to demonstrate the intravascular position of the cancer cells with the same degree of certainty, but the presence of epithelial cells in passages lined by endothelium is regarded as weighty evidence that the position of the cancer cells is intravascular, although it has not been possible to show definitely that the passages are blood channels.

3. The objection to the embolic theory, which is based on the fact that the distal bones of the limbs are extremely rarely affected by secondary carcinoma, is dependent upon a deficient appreciation of the anatomy of the bone-marrow. The embolic theory demands, not only that the carcinoma cells should have access to the blood-stream, but that they should settle in a tissue and proliferate there. The settlement of an embolus demands the presence of certain anatomical factors, such as slowing of the blood-stream

and a complication in the course of the vessels. These desiderata are found in the red bone-marrow, although they are not present in the fatty marrow. The red bone-marrow is a place in which the stream-bed of the blood widens, the course of the vessels becomes more complicated, and the conditions for the lodgement of an embolus become correspondingly more favourable. Red marrow with its wide blood channels is absent from the distal bones of the limbs and also from the distal parts of the proximal bones, and therefore these places are unfit for the settlement of emboli.

4. The site of the earliest metastatic tumours of bones is in the medullary cavity, at the lower edge of the red marrow in the proximal bones of the limbs. Fracture does not occur until tumour tissue has spread along the shaft of the bone to a place where the compact bone is fairly thin. The spread of tumour tissue is preceded by a spread of red marrow. If there is hyperplasia of the red marrow in the bones, owing to previous anæmia, the first deposition of metastases will not necessarily be at the upper end of the medullary cavity, but may be at the lower part of the hyperplastic red marrow.

5. The slowing of the blood-stream in the red marrow operates in a very definite manner: it results in the solid elements of the blood being sent to the periphery of the stream. This is seen frequently enough in the phenomenon of 'pavementing' of the leucocytes in the process of inflammation. Epithelial cells are certainly solid elements when compared with red corpuscles, and would, therefore, pass to the periphery of the blood-vessels of the marrow and proliferate there, where there would be little interference with their further development.

6. The grave changes in the composition of the blood picture are only explicable on the basis of an intravascular trauma to the marrow, as extravascular injury would result in changes in the distribution of the white cells of the blood: this latter type of change is well seen in cases of lymphadenoma affecting the bone-marrow.

7. The route by which emboli reach the arterial stream is not certain in all cases, but the work of M. B. Schmidt has demonstrated the frequency with which the vessels of the lung contain thrombi consisting, in part, of epithelial cells derived from a primary carcinomatous growth. These cells may be destroyed in the vessels of the lungs, but some of them may grow through the thrombus material and so give rise to emboli which are capable of colonizing elsewhere. This process would perhaps account for recurrences of carcinoma many years after removal of the primary growth. This explanation of the occurrence of late metastases is at least as plausible as the theory of uninterrupted permeation of lymphatic channels for a period of years.

8. The lack of observations on the involvement of the deep fascia in some of the cases of metastatic involvement of bones is another piece of evidence against the theory of lymphatic permeation.

9. The points at which carcinomatous metastases reach the surface of an affected bone correspond to the foramina through which the veins emerge.

IX. CONCLUSIONS.

The present investigation has led the writer to the conclusion that metastatic deposits in bones are due to arterial or capillary embolism. The main evidence which is brought forward is the detection of cancer cells in vascular channels in the bone-marrow. The vascular nature of these channels is demonstrated by the fact that they contain red corpuscles in addition to the epithelial cells. Evidence is also brought forward to show that the bone-marrow contains no lymphatic channels.

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SOME SURGICAL ASPECTS OF FILARIAL DISEASE.

By F. POWELL CONNOR, D.S.O., Lt.-Col., I.M.S., Calcutta.

Filarial diseases in tropical and sub-tropical countries are responsible for a multitude of surgical conditions, ranging from trivial ailments to surgical emergencies of the severest kinds. When one considers that millions of people are infected with this nematode, about which we know so much in some respects and so little in others, one cannot but feel attracted towards the subject.

It is amply proved that filarial infection can exist without any signs or symptoms being exhibited by the victim. In some cases this infection can persist for a considerable period and cause no disability, while in others the earliest evidence of infection may be a serious lymphatic obstruction, inflammation, or other surgical complication.

F. bancrofti and *F. medinensis* are the two parasites responsible for the greatest amount of suffering as regards human beings, their definitive host. The life-history of *F. medinensis* is well known, as are the inflammatory processes associated with the extrusion of the adult female from the tissues of the human host. But there is also a not uncommon class of surgical complications produced by this parasite to which I would like to refer, as sufficient attention has not been paid to them in the literature of the subject. These are the protean signs and symptoms which may arise from the irritative lesions directly due to calcified pieces of the dead worm remaining buried in the tissues. Acute or chronic cases of myositis, synovitis, inflammations of nerves, fibrous tumours, or abscesses, and many kindred affections, may be met with, and offer considerable difficulties as regards diagnosis. Such sequelæ may not appear until months or years after the death of the worm, but the history of the eruption of other guinea-worms, or even the fact that the patient comes from a part of India where the worm is known to be common, should give rise to suspicion as to the real cause of the trouble.

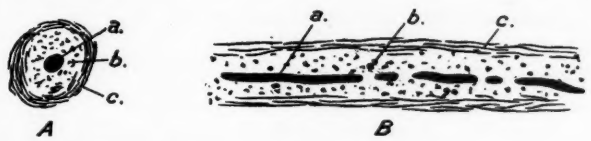

Fig. 188.—Diagram to show the structure of the calcified cord. *A*, cross section; *B*, longitudinal section. *a*, central axis; *b*, the middle coat; *c*, the outer coat.

The importance of realizing the surgical significance of the remains of the calcified guinea-worms in the tissues was only impressed upon me when acting as Consulting Surgeon to the Mesopotamian Expeditionary Force. Almost every Indian race was represented in the Force, and I was given an opportunity of studying guinea-worm affections in patients coming from some of the most heavily-infected Indian provinces. A brief reference to a few selected cases will serve as illustrations.

A young Madrasi complained of pain in the scrotum. On examination a cord was felt about four inches long and rather thicker than the ordinary clinical thermometer, occupying the loose areolar tissue outside the left tunica vaginalis. It was hard, but not brittle, easily movable, and with two free ends. There was no tenderness. A round elastic mass, about $\frac{1}{4}$ in. in diameter, could also be felt attached above and behind the left epididymis. A radiogram proved that these were calcified guinea-worm remains.

In this case, as in many, the calcified cord had a moniliform outline on the *x*-ray plate. After removal by operation the structure of the cord resembled the roughly-drawn diagrams *A* and *B*, representing a cross-section and longitudinal section respectively (*Fig.* 188). The central axis (*a*) was fragmented, hard, and calcified, and this was surrounded by a middle coat (*b*) of putty-like consistency and an outer coat of fibrous tissue (*c*). The print of this radiogram has faded too much to be worth reproducing.

A store-keeper, age 35, was admitted into hospital complaining of a painful mass above the right heel. A hard, irregular tumour was felt in and around the tendo Achillis, flattened from before backwards, and with irregular edges projecting beyond the tendon laterally and anteriorly. The *x*-ray print (*Fig.* 189) illustrates the condition admirably, except that the dense fibrous tissue surrounding the calcified cord is not shown.

FIG. 189.—Showing calcified guinea-worm remains in right heel.

This patient had been infected with guinea-worm in Jodhpur State during three years' residence there, and stated that twenty-one worms had been extruded from his legs, all below the level of the knees.

Other instances of this interesting surgical condition are shown in the *x*-ray prints (*Figs.* 190, 191, 192, 193). The diagnoses made in these cases were, respectively, chronic rheumatism of the ankle-joint, chronic traumatic synovitis of the knee-joint, periostitis, and sciatica. This proves how very baffling these conditions may be, and how ineffectual the treatment is until their true nature is ascertained.

As a general rule excision of the calcified cords is the proper treatment, but this can be very difficult, and in some instances the amount of disability may not justify an extensive dissection. Several patients were quite content to suffer a certain degree of pain or disability rather than undergo an operation.

FIG. 190.—Calcified guinea-worm infestation diagnosed as chronic rheumatism of the ankle-joint.

Surgical affections connected with infestation by the *F. bancrofti* are very numerous. They may be broadly classified as being either inflammatory in nature or due to lymphatic obstruction, and quite often these two types are combined. Some of the well-known complications and sequelæ are :—

1. Filarial fever, which is often associated with elephantiasis, cellulitis, orchitis, etc. The only evidence of infection in other cases is the presence of microfilariæ in the blood. Erysipelatoid attacks may also occur at irregular intervals.
2. Abscess and gangrene, most commonly scrotal.
3. Orchitis, acute hydrocele, acute arthritis or synovitis.
4. Lymphatic varices, fistulæ, gland varices, lymph scrotum.

5. Chyluria and chylous effusions into the peritoneum, tunica vaginalis, etc.
6. Elephantiasis of the scrotum, legs, arms, mammæ, vulvæ, and skin.

These complications vary much in severity, and though in rare instances they may rapidly prove fatal, in the great majority of cases the effects are transient, though liable to recur at decreasing intervals and with increasing severity.

FIG. 191.—Another case diagnosed as chronic traumatic synovitis of the knee-joint.

FIG. 192.—Another similar case mistaken for periostitis.

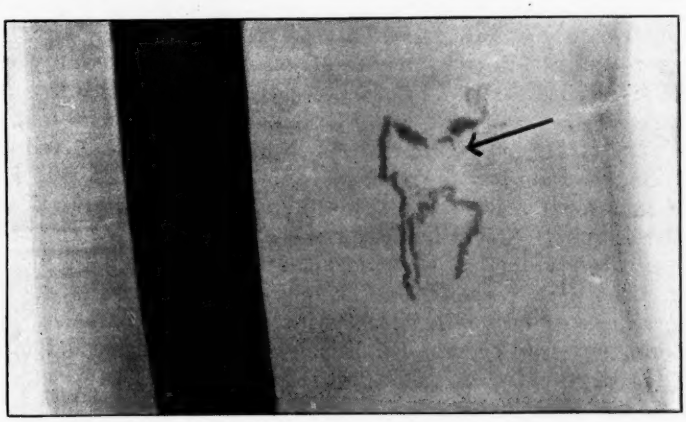

FIG. 193.—A case of calcified guinea-worm remains diagnosed as sciatica.

It will not be necessary to describe even the more important of these surgical affections, as they are all well known and fully described in text-books on the subject.

There are many problems connected with filariasis which still await solution. We cannot account for the age incidence of the various complications, because we do not know how long it takes for the parent worm to develop in the tissues and produce free

embryos. Surgical complications scarcely begin to appear before the age of 10 years, they are most common in years 20–40, and after 50 years become quite uncommon.

We do not know why hyperfilariasis does not occur in more patients continually exposed to the bites of infected mosquitoes, and though it appears that all classes are liable to infection, why is it that some individuals escape altogether? The wife may be infected and the husband escape. Women appear less liable to infection than men, and perhaps the poorer classes are more infected than those who are better off.

Probably gravity has a good deal to do with the common infection of such parts as the scrotum, the external genitals, legs, etc. These parts also contain large numbers of lymphatics. Whether the warm and moist surfaces in these regions help filarial growth we cannot say.

Elephantoid enlargements are the most obvious surgical complications which we believe to be associated with filarial diseases. But there is no certain chain of evidence to prove to us how these hypertrophies occur. They are only found in regions where filariasis is common, and there is much evidence to prove that filarial infection is the necessary link in the etiological chain. But I am not at all satisfied that we know the exact pathology. Is it the microfilariæ which are responsible? We know them to be apparently innocuous in the great majority of cases when found in the circulating blood, but it may be otherwise if they are shut off in a confined space by blocked lymphatics. Under such conditions the restless movements of their teeming millions may well produce irritative effects on the endothelial walls. Though adult filariæ may block large lymphatics and lymph glands, it does not seem likely that they can produce such extensive lymph stasis as occurs in these cases. Their living bodies or calcified remains are not found in sufficient numbers to account for the œdema and fibrosis which result. One must remember, however, that in the case of such minute nematodes, absorption and disintegration of their tissues would occur in a very short space of time.

We are forced to conjecture that elephantoid thickenings are the result of either the irritative or toxic effects produced by the worms or ova, or that some concomitant infection such as a streptococcal invasion is responsible. We have ample evidence that such streptococcal invasions do occur, in that erysipelatoid inflammations commonly complicate the cases, and streptococci can be readily obtained by puncturing lymph spaces or lymphatic glands. These attacks exhibit an extraordinary periodicity which it is not easy to account for, unless it be that the intervals between the attacks represent the period of short immunity produced by each exacerbation.

There are several other points which are of interest in connection with this secondary streptococcal infection. It was found during the war that tissues infected by streptococci —generally introduced with multiple minute foreign bodies, such as fragments of missiles— were liable to a very serious inflammatory reaction if again interfered with, even when weeks or months had passed after the original injury. This is not true in the case of the erysipelatoid inflammations affecting elephantoid enlargements. Surgical operations can be performed with impunity on filarial tumours a short time after an attack of inflammation has subsided. It is true that suppuration is not unknown in such cases, but it is quite uncommon. It is even possible to implant gross foreign bodies, such as large strands of silk in the operation of lymphangioplasty introduced by Sampson Handley, without necessarily reproducing a streptococcal cellulitis. It therefore seems obvious that the streptococci met with in these cases are not of an intensely virulent type.

It is a curious fact that in the case of the calcareous threads left behind quite often after the death of adult guinea-worms, and generally broken up in a moniliform manner, we seldom meet with a similar streptococcal invasion. In these cases the foreign body is a large one, and one would expect a greater degree of tissue irritation.

One must admit that the pathology of these erysipelatoid inflammations in connection with filarial enlargements is not at all well understood. Given a streptococcal infection, the solid œdema and fibrous thickening of the subcutaneous tissue is easily explained. It is exactly what is met with after many attacks of cellulocutaneous erysipelas in non-filarial cases. An infant under my care a short time ago had had several attacks of cellulitis of

this type, resulting in a brawny œdema of the legs. It is now slowly disappearing, but one can readily imagine that consecutive attacks at regular intervals would cause a good deal of fibrosis and produce a condition of elephantiasis not differing in any essential respects from the cases generally described as filarial.

A very acute condition described as 'septic phlebitis of the spermatic cord' by the late Colonel R. Bird, I.M.S., and also known as 'funiculitis' (Castellani), occurs in India. This is a very dangerous form of streptococcal invasion of the spermatic cord rapidly spreading upwards and downwards and causing streptococcal septicæmia, if not promptly dealt with by surgical methods. I have often wondered whether some of these cases are initiated by filarial infections. The terribly acute nature of this streptococcal invasion is, however, rather in contrast to less severe types met with commonly in filariasis. But the wholesale lymph stasis in the latter, which is absent in funiculitis, may to some extent explain this. I would be glad to know whether any experiments have been carried out to ascertain the degree of virulence of the strain of streptococci commonly found in filarial infections.

The etiology of hydrocele in India has been very little worked out. Undoubtedly some of these cases are filarial, but in a great many patients no evidence of this infection exists. Specimens of fluid from ten cases were examined recently; none of these produced any growth on culture, two showed numerous filarial embryos, one numerous spermatozoa, while in most cases tyrosin and cholesterin crystals—particularly the former—were abundant. In many instances the cord presents no evidence of thickening or disease, but small patches of subacute inflammation can be found on the epididymis. No further clue, however, has so far been found to account for these patches. Of the many methods of cure practised in India for hydrocele, open operation is the only one which can be adopted as a radical cure. Various modifications are carried out by surgeons; but it may be fairly stated that they all attempt to achieve the desired result either by removal of the secreting layer of the parietal tunica vaginalis or by its eversion or plication. It would be of great labour-saving value if, by some non-irritating chemical or bacterial agency, the endothelial lining of the tunica vaginalis could be obliterated without causing injury to the testis or neighbouring tissues. It is also possible that a permanent filtration channel could be devised, on the lines attempted in ascites, by implanting a foreign body or a piece of fascial tissue in a window created for the purpose in the parietal wall of the tunica vaginalis. The open operation is a very satisfactory one; but in districts like Bengal and Orissa, where a large percentage of the population is affected in this way, a simpler procedure is badly needed.

Great ingenuity has been exercised by surgeons in devising operations for elephantoid enlargements. A very brief reference to some of them will be made here. Generally speaking, the surgery of pendulous thickenings is very successful, but similar affections of the extremities are much more difficult to deal with.

In the lower extremity, decortication of the whole affected area followed by skin-grafting and 'lymphangioplasty' (Sampson Handley), is not a very satisfactory procedure. The removal of considerable strips of tissue, muscle-deep, from the lowest part of the swelling to a region of healthy tissue above (Kondoléon), has been found to be the most successful operation.

The operation for the removal of elephantoid enlargements of the scrotum and sheath of the penis is one which has developed a good deal within recent years. Considerable variations exist in the type of operation performed in various parts of the tropics. The following points sufficiently indicate the procedure followed by me:—

1. The incision varies with the size and variety of tumour, and is not very important except that the perineal flaps should be made as wide as the healthy tissues will allow of. In very large tumours it is wise to isolate and lay bare the penis and testicles before fashioning the perineal flaps. In the case of smaller tumours it is quicker to cut these flaps and expose the testicles from behind, and deal with the penile sheath last.

2. Much time is saved by tearing through the tissues with gloved fingers as soon as the soft œdematous layers are reached.

3. Blood-vessels, which are generally of considerable size, should be tied with catgut after clamping; twisting is not a safe procedure.

4. The testicles should be accommodated beneath the perineal flaps, when these are sufficiently large to cover them. Failing this, they can be placed more easily in pockets excavated by the gloved fingers in the subcutaneous tissues of the adjacent parts of Scarpa's triangle.

5. Drainage is not generally necessary.

6. It is important to fix the fibrous sheath of the penis at its base by catgut sutures to the adjacent skin edges, to prevent retraction. I never utilize the preputial mucous membrane, though often tempted to do so, to cover the distal portion of the raw surface of the penis: it is very liable to solid œdema. Skin-grafting can be done at once or after a week by Thiersch's method.

7. The efficient dressing of these cases is most important, and the method introduced by the late Colonel C. R. Stevens, I.M.S., is very suitable. It is by means of rolls of 1-inch lint soaked in 1 per cent picric lotion or normal saline. About four inches of the beginning and end of each roll are applied in turn to the surface of the belly, perineum, or inguinal region, while the central parts of the bandages are wound round the penis. These tails are then held down by an ordinary double spica bandage after the usual dressing of gauze and cotton-wool has been applied. The lint becomes sufficiently stiff on drying to keep the penis comfortably cased.

8. Every precaution must be taken to prevent any soiling of the wound by urine.

The only weak part of this operation is the Thiersch's skin-graft of the penis. No suitable flap or modification of the Indian operation (as for rhinoplasty) has yet been devised to replace it. Quite recently I have tried a new device and have been astonished at the success obtained. This consists in cutting a sufficiently large flap from the thick œdematous tissue covering the region of the dorsum of the penis. This is pared down at the end of the operation with a razor and curved scissors till it is barely thicker than the normal skin of the penis and is then used to cover up that organ completely. Contrary to expectation, this skin has become quite soft and pliable after a few days, and if this result is always obtained, this procedure will remove the only real defect of the operation. It would seem that the skin and subcutaneous tissues of the dorsum of the penis and of the pubes are quite capable of filtering off their own lymph if not embarrassed by the lymph stasis of the scrotum and neighbouring parts.

UNUNITED FRACTURES DUE TO WAR INJURIES: WITH END-RESULTS OF OPERATIVE TREATMENT IN 100 CASES.

By A. PHILP MITCHELL, Edinburgh.

As a result of the frequency of ununited fractures in gunshot injuries of the extremities, the operation of bone-grafting acquired greater importance and has required to be extensively practised. In this paper it is not proposed to discuss the relative merits of the operations in use and experimental work that has been done in regard to the fate of bone-grafts, but to record the results of the experience gained from a personal study of 77 patients in the Military Orthopædic Hospital at Bangour during a period of three years ending March 31, 1921, and also of 23 cases during a period of eighteen months in Craigleith Ministry of Pensions Hospital; to describe the operations which the writer was led to adopt; and, by illustrative cases, to bring forward for consideration some of the important points in connection with the pre- and post-operative treatment.

The question of the fate of bone-grafts when in process of conversion into normal bone is reserved for a subsequent communication in which the results of an experimental investigation, not yet complete, will be fully discussed.

GENERAL CONSIDERATIONS.

In 61 cases the operation carried out by the author has been a primary one aiming at bone replacement, and in 24 cases unsuccessful attempts had been previously made by other surgeons.

It is important to note that the hundred cases for this study are unselected. The gap between the ends varies from 1 to 12 cm. and is filled with fibrous tissue. The fragments are frequently tapering, brittle, and sclerosed, and the medullary canal is closed. When this osteosclerosis is extreme, it extends for two or three inches along each fragment, the periosteum being replaced by fibrous tissue. The surrounding soft tissues are also fibrosed and adherent to the bone. As such tissues bleed freely, and the bleeding is difficult to arrest—this being a not uncommon occurrence in cases of the tibia and humerus—a complete excision of all fibrous tissue is advisable. The presence of lurking bacteria with a hæmatoma might result in failure of the operative treatment.

The importance of general causes of non-union of fractures is largely academic, and it is to be emphasized that local causes play a vastly greater rôle. The causes acting locally in the cases in the present series were as follows:—

1.	Primary loss of substance	55 cases
2.	Displacement	12 „
3.	Sclerosis and latent sepsis	5 „
4.	Sclerosis with plating and wiring	4 „
5.	Sclerosis and gap	12 „
6.	Sclerosis	12 „

The publication of the results has been delayed so that a sufficient period might elapse for most of the patients to resume civil employment and test the strength and utility of the reconstructed limb. Since the majority of the patients are pensioners from Edinburgh and neighbouring counties, it has been possible to keep them under observation from the time of operation up to the present date, and to make frequent radiographic examinations.

Table I.—Analysis of Cases.

Bone	Number of Cases	Union by Operation	Failure	Partial Success	Union by Conservative Treatment	No Treatment required owing to Slight Disability
Ulna ..	Left = 26 Right = 10	30	0	0	0	6
Radius ..	Left = 18 Right = 8	20	1	1	3	1
Humerus ..	Left = 6 Right = 13	16	1	2	0	0
Tibia ..	Left = 4 Right = 11	10	1	0	4	0
Femur ..	Left = 2 Right = 1	1	0	0	2	0
Fibula ..	Right = 1	0	0	0	0	1
	Total 100	77	3	3	9	8

PRE-OPERATIVE TREATMENT.

The operation result and ultimate function of the limb are influenced to some extent by the nature of the pre-operative treatment that has been employed. Whilst the bone lesion may be the chief cause of the resultant disability, other tissues have frequently suffered considerable damage with consequent loss of function. A prolonged sepsis of the gunshot wound has frequently resulted in considerable destruction of muscle tissue and loss of function—marked limitation of pronation and supination, stiff fingers, and maybe loss of movements at the wrist, elbow, or shoulder joint; and lastly, an important nerve may have been severed or partially destroyed. All cases should have the benefit of hydrotherapy, massage, and active and passive exercises.

As regards deviation of the hand resulting from non-union in the lower third of the radius or ulna, very little can be done at a late stage by pre-operative treatment, but in the early cases this deformity can be avoided by means of a short plaster-of-Paris splint. This pre-operative period therefore need not be wasted, as non-union is seldom the only thing wrong with the limb.

OPERATIVE TREATMENT.

As it is impossible to state after what period gunshot wounds are quite free from the danger of latent sepsis, my practice has been never to proceed to the bone-graft operation until the wound has been soundly healed for at least twelve months. Referring to the tabulated data of the cases, it is shown that in most instances the original wounds had been healed fifteen months or longer before the patients came under my care for the appropriate reconstruction operation. Further, it is interesting that latent infection was first encountered in 6 cases all operated on within the last year.

Since there is no sure means of determining whether or not latent infection exists, an operation in two stages has been carried out by some surgeons. Such a procedure should certainly be adopted where prolonged sepsis of the original wound has resulted in extensive scarring of all tissues at the site of non-union. At the preliminary operation all sclerosed tissue is completely excised. The wound is then closed and a period of fourteen days allowed to elapse before proceeding to the grafting operation. Should a flare-up occur during this period, the infection can be much more easily controlled than if the complete operation had been carried out. But infection and a successful graft are

not incompatible. *Case* 17 illustrates this ability of a graft to thrive despite severe infection of the surrounding tissues. *Figs.* 194 and 195 show the condition present before, and five months after, operation. Nevertheless, of the attributable causes of failure in bone-grafting, it must be admitted that, above all other causes, sepsis is the great bane of this operation.

The key-note of surgery in ununited fractures should be absolute simplicity. The most perfect carpentry will not be followed by osseous union strong enough to restore satisfactory function if, in carrying out the graft operation, the following anatomical, pathological, and general technical principles have received insufficient attention :—

FIG. 194.
Ulna from *Case* 17.
Before graft operation.

1. The importance of making the skin incision of sufficient length.
2. Complete excision of scar-tissue and removal of sclerosed bone until healthy vascular bone is exposed.
3. Extensive surface of contact between graft and host-bone.
4. The preparation of a healthy muscle bed.
5. The avoidance of metallic or non-absorbable sutures for internal fixation of graft.
6. Scrupulous attention to asepsis and perfect hæmostasis.
7. Immobilization by plaster-of-Paris until firm osseous union has occurred between graft and host-bone.

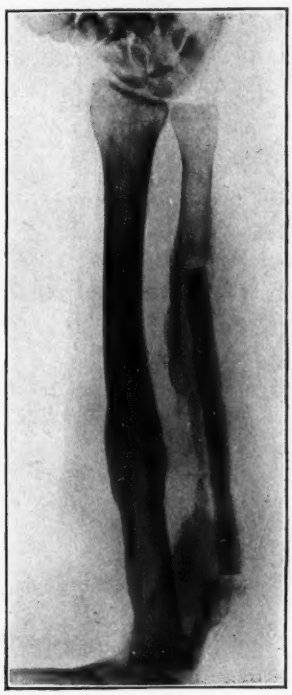

FIG. 195.—The same case as *Fig.* 194. Graft survived severe latent infection. Callus thrown out from the ends of host and new bone creeping along the graft. Five months after graft operation.

In every case of ununited fracture the success or failure of the operative treatment will depend upon the correct appreciation of these factors. The inlay cortical graft as popularized by Albee has not proved so successful as may have been expected in ununited war fractures. The technique of this operation will not permit of the placing of a very broad piece in the fragments, and it was on account of many failures observed that the author was led to try a different type of operation. Practically all failures can be definitely attributed to technical errors, such as too small a graft, infection, or inadequate fixed bony approximation of the graft to the host-bone.

Before describing in detail the operation that has given excellent results, it is desirable to consider briefly certain important factors in regard to the bone-graft itself.

In my experience the autogenous tibial graft, including periosteum, compact bone, and medullary tissue, has proved most satisfactory. The bone is easy of access and from it a graft can easily be cut of any shape, length, or thickness required. Rapid regeneration of bone soon fills the gap left in the tibia, so that no permanent disability results. Occasionally a hæmatoma may develop, but no serious complications have ever occurred. As a rule, the wound is strongly healed at the end of a fortnight.

In very few cases were grafts free of periosteum employed. The results of those in which the periosteum was not included were just as satisfactory. Although no reliance can be placed on the periosteum for production of bone, I am satisfied that it facilitates the secondary vascularization of the graft and also protects the graft in the event of the lighting up of latent sepsis. Stripping up of the periosteum during the course of an

operation should therefore be carried out with the greatest care, and to the minimum amount, to avoid underlying necrosis should infection ensue. It has been my practice, when intramedullary grafts were considered necessary, and employed successfully in 7 out of 10 cases, to remove the periosteum from that part of the graft which is fitted into the medullary cavity of the host-bone. Whilst the compact bone does not seem to take an active part in osteogenesis after transplantation, it supplies the strength to withstand the strain of function when union is complete.

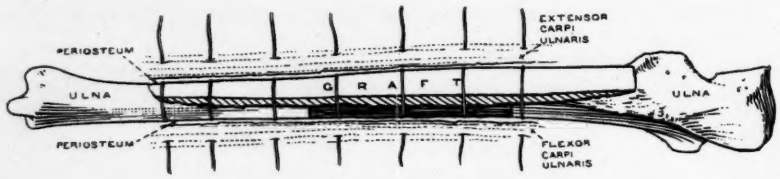

FIG. 196.—Diagram showing autogenous massive tibial graft as employed in ununited fracture of ulna.

The medullary tissue, however, would appear to be the main route along which new bone formation extends between the fragments of the host-bone. It is, therefore, advisable to include as much as possible of this tissue in any graft (*Fig.* 196).

The size of the graft is important. It must be cut long enough, not only to bridge the gap, but to have contact with a wide surface of the host-bone on either side. The

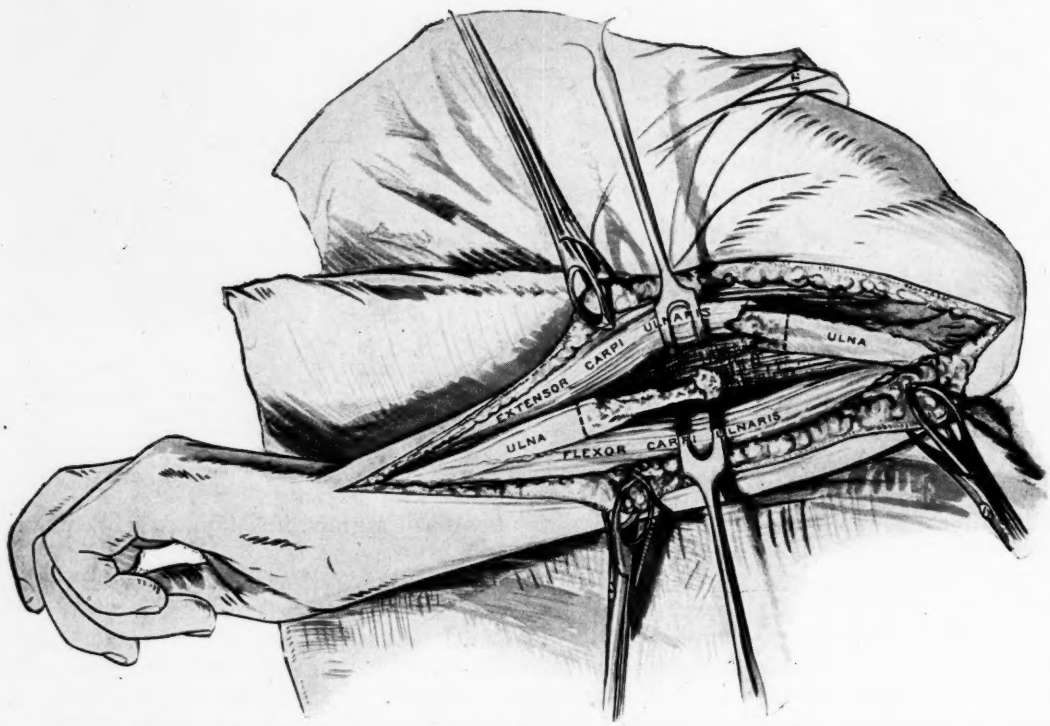

FIG. 197.—Diagram showing skin incision and dissection to prepare ununited fragments of ulna and musculo-osseous bed for reception of graft.

usual length is found to be from two to three times that of the gap. This is an important technical point, and cannot be too strongly emphasized. The graft is seldom less than four inches. A long graft affords, not only better and firmer fixation, but also a larger surface of contact between the host and the graft, which increases the means of access for

the new blood-supply. Further, the more the graft approximates in size to the bone to be replaced, the less liable it is to fracture, and the more quickly will full strength be obtained in the reconstructed limb.

I now come to the operation which has engaged my special attention for some time past. No claim is made as to its being entirely original in conception, but its application in a large number of ununited war fractures having proved so highly successful seems to justify my personal experience of its effectiveness being put on record.

In my experience the autogenous graft obtained from the subcutaneous inner surface of the tibia, and employed as a massive lateral graft, has formed the most satisfactory method of dealing with non-union of the ulna, radius, and tibia following upon gunshot injuries. The operation will be described as it is carried out for the ulna.

The bone should be approached along its postero-internal border between the flexor and extensor carpi ulnaris. Too great emphasis cannot be placed upon the importance of making a skin incision of sufficient length (*Fig.* 197).

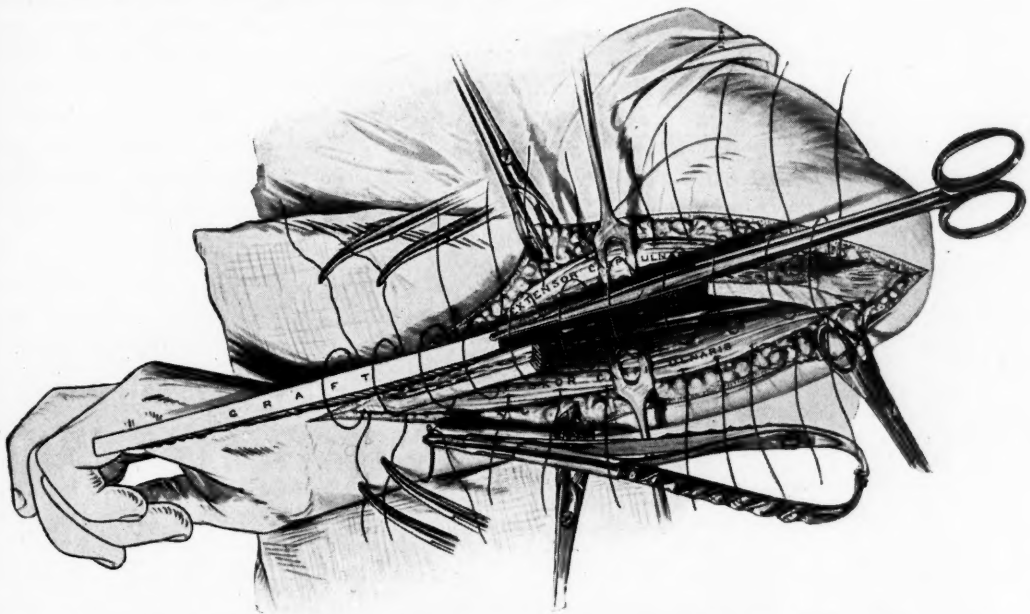

FIG. 198.—Diagram of musculo-osseous graft and bed on postero-internal surface of ulna completed. Method of placing graft under looped sutures of strong tanned catgut.

The first step of the operation should be to excise all scar-tissue, whether in the skin or deeper tissues. In regard to the former, this should be done as a preliminary operation whenever the skin cicatrix is extensively adherent to the underlying structures. Otherwise, if a large skin scar has been left to cover the tissues, it will, within a few days, necrose in part and leave a troublesome superficial ulcer to heal. The deep scar-tissue between the bone fragments must also be regarded as tissue of poor vitality, deficient circulation, and weak resistance. Such a preliminary operation was carried out in 10 cases. A bone-graft implanted in scar-tissue would most probably be absorbed, or at least atrophy, and fracture easily.

In the next step of the operation the ends of the host fragments are exposed, and all sclerosed and ragged bone between the fragments removed until healthy vascular bone appears. All sclerosed bone is of very low osteogenetic power. The muscles, along with the periosteum, are then stripped from the bone for fully two inches from the fractured ends, and for practically one-fourth of the circumference of the bone (*see Fig.* 197). Next, beginning in a direction away from the point of fracture, and extending the whole

length of the exposed bone, a thin layer of bone is removed with a fine osteotome or chisel, the cut being made deep enough to expose the medullary canal in places. The same procedure is repeated in the other fragment. Care should be taken that the bed for the graft is cut on the surface of the fragments that will be in continuity when the limb is in the desired position. In most cases it is found convenient to prepare the osseous bed for the graft on the postero-internal surface of the ulna (*Fig.* 198).

Internal fixation of the graft is most essential for a successful result, and depends to a considerable extent upon accurate suturing. Interrupted sutures of strong 'tanned' catgut have been employed throughout the series almost without exception. They are passed through the reflected periosteum and muscles on either side of the prepared bed (*Fig.* 199). Metallic sutures generally were not used, on account of the irritation and atrophy of the tissues they are liable to produce. They are necessary at times—for example, in the humerus—but always to be avoided if possible. No difficulty need be experienced in securing firm fixation by catgut, provided the loop method is employed (*Figs.* 198 and 199). The musculo-osseous bed is now ready for the reception of the tibial graft.

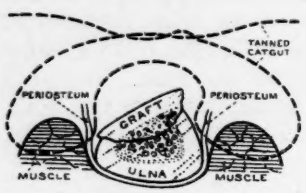

FIG. 199.—Diagram showing method of introducing looped tanned catgut sutures for fixation of graft.

It is clear that in the method described an extensive surface of contact is obtained between the graft and the freshened bone, and the medullary surface of the graft is in close apposition to the openings into the medullary canal. Broad and accurate contact, efficiently maintained, is the best guarantee of rapid and strong union (*Fig.* 200).

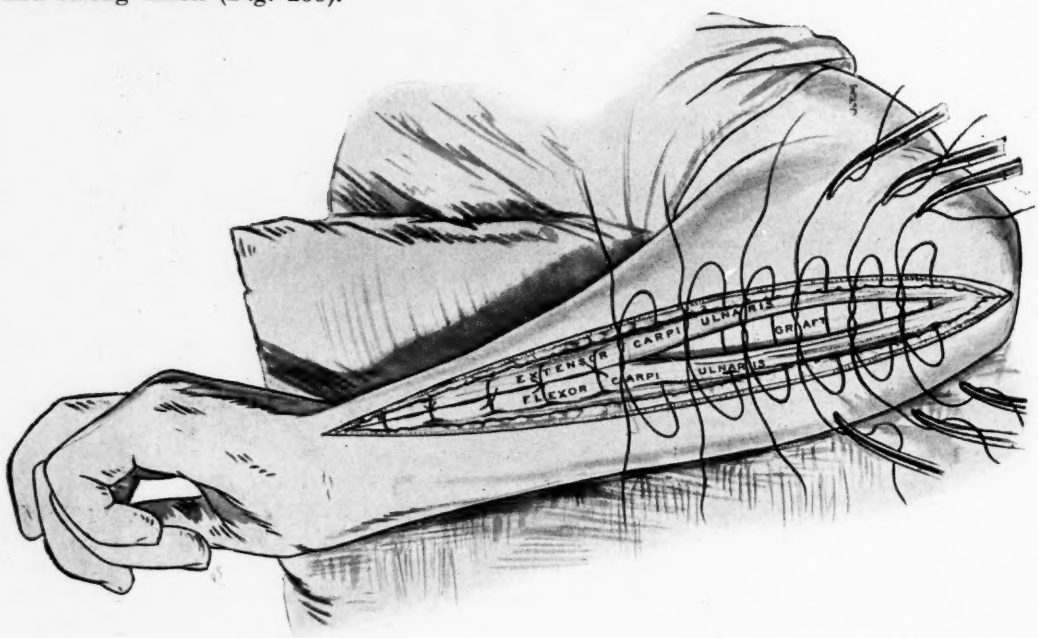

FIG. 200.—Diagram showing graft in position and broad and accurate contact maintained by tanned catgut sutures.

A pliable probe is laid in the defect and bent to the exact length of the graft required. The wound is packed with gauze to stop oozing, and covered with a sterile towel whilst the graft is obtained. An incision of suitable length is made along the outer side of the anterior border of the tibia. The bent probe is then laid on the bone, and the exact length of the graft required is marked off. The portion to be removed is completely marked out by incising the periosteum. The removal of the graft is carried out by a

circular saw (preferably single) electrically driven. While the saw is cutting, it is constantly sprayed with saline solution. The transplantation should be made immediately. I am convinced that it is a mistake to wash the graft in saline lotion or leave it in saline while something else is being done. The best results follow immediate closure of the deep tissues round it, and suture of the surface wound. The graft is placed underneath the catgut loops as shown in *Fig.* 198, and held in close apposition to the raw surfaces of the parent bone whilst the ligatures are being tied. A few additional catgut sutures are necessary to unite the surrounding muscles and so ensure a complete covering for the graft (*Fig.* 200). The skin wound is closed with interrupted silkworm-gut stitches.

The limb must now be securely controlled in correct position by a plaster-of-Paris case, which is the only adequate post-operative dressing. It should be applied with the utmost care over a thin padding of cotton-wool or flannelette bandage, which fixes the wound dressing, moulded to the bony contours of the extremity, and should always include at least one joint above and one joint below the bone involved. In the forearm cases the position of the limb is important. The elbow is flexed to a right angle, and the forearm supinated as completely as possible. The limb should be held in the desired position throughout.

POST-OPERATIVE TREATMENT.

The protection of the graft from undue stress subsequent to the operation is best attained, in the writer's view, by the application of a plaster-of-Paris casing from the fingers to the mid-humerus and applied at the time of operation. The padding employed usually prevents any excessive swelling of the limb. However, should œdema develop, the cast ought immediately to be split down the whole length of the aspect furthest from the graft. The condition is quickly relieved and no harm is done. A plaster case may be made considerably lighter by reinforcing it at the points of special strain by wire or narrow strips of metal.

FIG. 201.—Ulna from *Case* 13. Massive lateral tibia graft united strongly with host-bone at both ends. Seven weeks after graft operation.

Absolute immobilization of the part involved is maintained for six weeks. During this period the graft is establishing a vascular continuity with the host at either end and with the surrounding tissues, and it is not necessary to interfere with the plaster case.

After the expiration of six weeks, the skin stitches are removed, and before a second plaster casing is applied the degree of union between the graft and host-bone is determined by a radiographic examination (*Fig.* 201). Success is unlikely if the graft is not firmly united with the host at both ends.

In the case of the forearm, the elbow is again flexed to a right angle, and a small window is cut on the anterior and posterior aspects of the forearm so that gentle faradic stimulation of the flexor and extensor muscles may be carried out. A small short cock-up splint should be incorporated with the plaster, to permit the hand being left free for exercises and massage without straining the graft. Such measures unquestionably stimulate bone growth by allowing the graft to functionate as early as possible and within the limits of safety.

At the end of three months from the date of operation the plaster is dispensed with, and the nutrition of the limb is gradually restored by massage, faradism, and active use.

The time involved by the change from the stage of partial function to that of complete function depends upon : (1) The presence or absence of other serious disabilities, e.g., nerve lesion, muscle destruction, etc. ; (2) The state of union between the host-bone and graft ; (3) The individual bone involved. The growth and union of the graft are easily estimated by radiograms, which should be taken every six or eight weeks (*Fig.* 201). During the transitional period it is advisable that the forearm be supported by the wearing of a short

cock-up splint, and particular attention be given to exercises to encourage the return of the movements of pronation and supination. As regards the tibia, the plaster casing should be worn for a period of six months at least subsequent to operation, and for a further three months an external metal support is essential. Such conservatism will certainly avoid the occurrence of some failures.

CONSIDERATION OF INDIVIDUAL BONES.

Radius.—Non-union of the radius is more important than that of the ulna, owing to the considerable weakness of grasp resulting. It may occur in any part of the shaft, but is especially frequent in the lower half (*Fig.* 202). In most cases a bone-grafting operation is necessary. The hand is attached to and articulates mainly with the radius, so that loss of the support of the latter owing to non-union is associated with considerable weakness of grasp, and with radial deviation of the hand, which deformity is kept up by contracture of the radial tendons, these stretching like a bow-string across the gap in the bone (*Fig.* 203). The lower fragment of the bone tilts towards the ulna and the hand is deviated towards the radial side, the styloid process lying at a higher level than that of the ulna (*Fig.* 204). Where the lower fragment of the radius is less than an inch in length,

FIG. 202.—Radius from *Case* 39. Non-union from the loss of bone between the fractured ends. Marked deviation of distal fragment, with consequent radial deviation of hand (*see Fig.* 203). For result of grafting operation see *Figs.* 205 and 208.

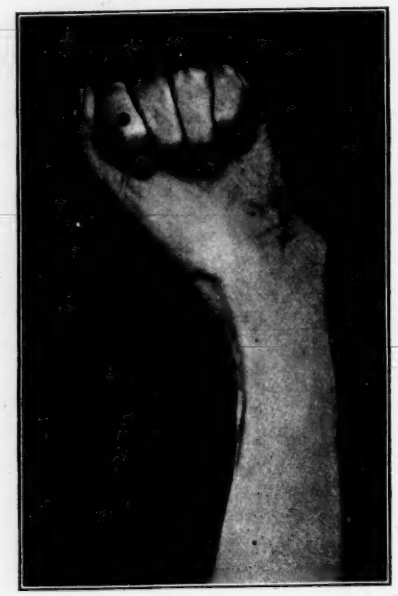

FIG. 203.—*Case* 39. Illustrates radial deviation of hand. Contracture of radial extensors of wrist well seen. For result after operation see *Fig.* 205.

FIG. 204.—*Case* 19. Large portion of shaft missing and considerable deviation of distal fragment. For result of grafting operation see *Fig.* 211.

shortening of the ulna to correct radial deviation and allow direct union of the radial fragments has been recommended. This procedure is not advisable, as it is sometimes followed by non-union of the ulna: the hand deviation can be as satisfactorily corrected by lengthening of the contracted radial tendons (*Fig.* 205).

There are often associated injuries of the tendons and muscles, particularly of the extensor muscles of the thumb. An injury to the median nerve is not an uncommon complication. Large adherent scars are also frequent, and are important because these may interfere with the success of an operation unless they can be completely removed at a preliminary operation.

The radius is best exposed along the line which separates the radial extensors of the

FIG. 205.

FIG. 206.

FIG. 207.

FIG. 205.—*Case* 39. Radial deviation of hand almost completely corrected by lengthening of contracted radial extensors of the wrist at grafting operation. For result of bone-graft see *Fig.* 208.

FIG. 206.—*Case* 34. Posterior subluxation of lower end of ulna, occasionally a complication of non-union of radius in its lower third.

FIG. 207.—Radius from *Case* 27. Modified intramedullary graft—pegging one end of graft into medulla, and the other fitted into gutter. Result 2½ months after operation. Ultimately strong union.

FIG. 209.

FIG 210.

FIG. 211.

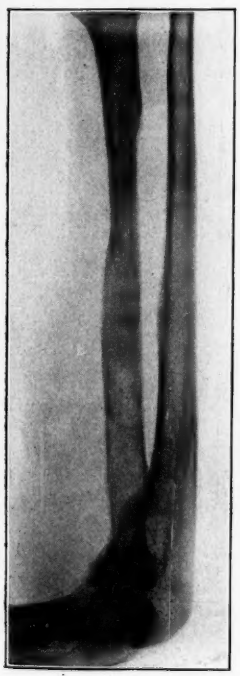

FIG. 208.

FIG. 208.—*Case* 39. Same as *Figs.* 202, 203, 205. Final result 29 months after grafting operation for non-union of radius, August, 1919. Medullary canal completely re-formed. Massive tibial graft employed.

FIG. 209.—*Case* 20. Final result of tibial graft for non-union of radius—three years after operation, February, 1919. Complete canalization of graft.

FIG. 210.—*Case* 41. Final result of tibial graft for non-union of radius—two years after operation, January, 1920. Canalization of graft almost complete.

FIG. 211.—*Case* 19. Same as *Fig.* 204. Final result of tibial graft for non-union of radius—22 months after operation, November, 1919. Lengthening of flexor carpi radialis and brachioradialis in addition to radial extensors of wrist required to correct extreme degree of radial deviation of hand.

FIG. 212.—Ulna from *Case* 2. Large portion of shaft missing. For result of grafting operation see *Fig.* 219.

wrist from the extensor communis digitorum. In its distal third the extensor pollicis brevis and the abductor pollicis longus crossing the tendons of the radial extensors of the wrist often render access to the tilted lower fragment somewhat difficult; whereas exposure in the upper two-thirds is a comparatively simple dissection. To secure proper alinement it is necessary to lever the lower fragment away from the ulna and to rotate it into the supinated position. A slight radial deviation of the hand may remain, but this is not of importance. A posterior subluxation of the lower end of the ulna (*Fig.* 206) is by no means a rare complication, and occasionally gives rise to pain in the neighbourhood when the patient has resumed his employment, and particularly if this is of a laborious nature.

The graft is preferably applied to the posterior surface of the host-bone. In fractures above the level of the insertion of the pronator radii teres, it is important to remember that, whereas the proximal fragment is found completely supinated, the distal is fully pronated. In some cases when the site of non-union is close to the wrist-joint it is impossible to obtain a satisfactory bed and coverings for a lateral graft.

FIG. 213.—Ulna from *Case* 3. Non-union middle of shaft. For result of grafting operation see *Fig.* 221.

FIG. 215.— Ulna from *Case* 5. Non-union in upper third. Proximal fragment flexed and tilted towards the radius. For result of grafting operation see *Fig.* 217.

FIG. 214.—Ulna from *Case* 9. Condition of non-union when patient admitted to Bangour Hospital.

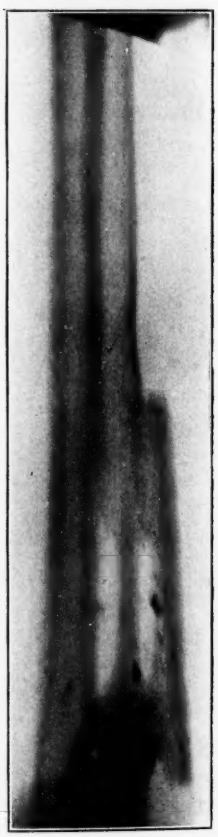

FIG. 216.—*Case* 5. Same as *Fig.* 215. In addition to massive tibial graft an intramedullary peg was employed to correct deviation of proximal fragment. For operation result see *Fig.* 217.

FIG. 217.—*Case* 5. Same as *Figs.* 215, 216. Final result 18 months after double graft—intramedullary and lateral massive.

FIG. 218.—*Case* 13. Same as *Fig.* 201. Final result of tibial graft for non-union in upper third of ulna — 8 months after operation, September, 1921.

Firm fixation of the graft is also essential. For such cases a modified intramedullary peg proved successful. This method consisted of pegging one end of the graft into the medulla of the proximal fragment and fitting the other into a gutter made in the short distal fragment (*Fig.* 207).

Ulna.—Non-union of the ulna is of frequent occurrence, but is much less important (*Figs.* 212–214). Whilst most ununited fractures of the radius require bone-grafting, some ununited fractures of the lower third of the ulna, or of the olecranon, cause so little disability that this is not necessary. When it occurs low down in the shaft it affects the utility of the hand comparatively little, and any deformity is slight.

There is usually no considerable displacement of the fragments to be corrected except when the

FIG. 219.—*Case* 2. Same as *Fig.* 212. Three months after grafting operation for large gap in ulna.

FIG. 220.—*Case* 3. Same as *Fig.* 213. Result 15 months after grafting.

FIG. 221.—*Case* 9. Same as *Fig.* 214. Final result 28 months after grafting operation for non-union of ulna.

fracture involves the upper third, the proximal fragment often being flexed and tilted towards the radius (*Fig.* 215). It is advisable to correct this deviation and maintain proper alinement by an intramedullary peg (*Figs.* 216, 217), this being additional to the usual lateral graft employed. Preliminary excision of the skin cicatrix has been more frequently required in the case of the ulna.

The ulna, being a less vascular bone than the radius, with usually a considerable thickness of sclerosed bone at the common site of non-union in the upper third, it is essential to prepare the best available musculo-osseus bed.

It is rare to find both bones of the forearm ununited. Shortening of both to allow direct union, and a bone-graft of the ulna to ensure adequate fixation, is probably the best operative procedure.

FIG. 222.—Humerus from *Case* 81. Non-union in middle third. For operation result see *Fig.* 223.

FIG. 223. — *Case* 81. Same as *Fig.* 222. Result 8 months after step-cut operation. Good union.

Humerus.—The cases of non-union of the humerus numbered 19, and generally constituted a difficult surgical problem.

FIG. 224.—Humerus from *Case* 68. Non-union in region of neck. For result of operation see *Fig.* 225.

FIG. 225.—*Case* 68. Same as *Fig.* 224. Result two years after squaring of fragments, intramedullary peg, and sowing of iliac bone chips. Good union. Function of shoulder excellent.

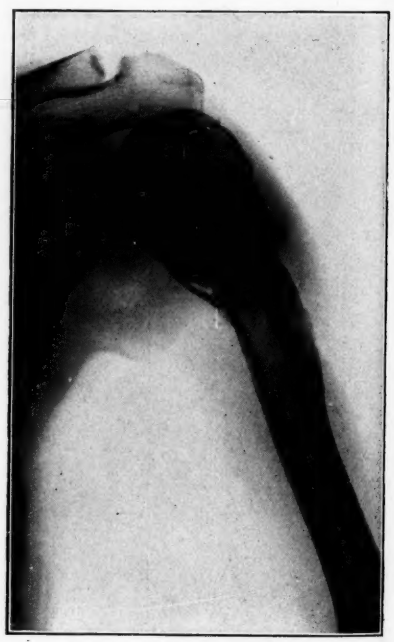

FIG. 226.—Humerus from *Case* 67. Non-union in region of neck. Result 32 months after intramedullary peg and squaring of fragments. Additional fixation by wire in case of absorption of intramedullary graft. Strong union. Function of shoulder excellent.

It has been stated that in proportion to the number of fractures sustained by this bone, non-union is more frequent than in any other bone in the body. The chief reason for this relatively high occurrence is that fixation is particularly difficult to maintain. Of

the patients, 2 had musculospiral paralysis at the time of operation, and 10 cases had been previously operated on elsewhere, not infrequently as often as three times. Freshening the ends of the bone and fixation by wiring, plating, and inlay grafting had been practised, and with persistence of

FIG. 227.—Humerus from *Case* 87. Non-union in region of neck treated by removal of sclerosed bone, impaction of distal fragment into the proximal, and obtaining internal fixation by kangaroo tendon. Result 7 months after operation. Strong union. Function of shoulder good.

FIG. 228.—Humerus from *Case* 94. Double graft employed. Absorption of intramedullary graft. For final result see *Fig.* 229.

FIG. 229.—*Case* 94. Same as *Fig.* 228. Result 16 months after grafting operation. Strong union.

non-union, which is found to occur frequently in the lower third of the shaft. These results clearly indicate the unsatisfactory nature of the operative procedure employed in the early humerus cases. Whilst all are agreed that the autogenous bone-graft has given the best results in the radius, ulna, and tibia, it cannot be employed so generally in the case of the humerus. Bone-grafting is of little value in filling gaps in the shaft of the humerus. Ununited fracture of the humerus is most certainly remedied by the step-cut operation, and the steps should be long (*Figs.* 222 and 223). Shortening of the arm is of minor importance. This method was successfully employed in 9 out of 10 cases.

FIG. 230.—Humerus from *Case* 93. Non-union in lower third. For result of grafting operation see *Fig.* 231.

FIG. 231.—*Case* 93. Same as *Fig.* 230. Final result 9 months after grafting. Very strong union. Function of elbow excellent.

Alternative operative measures are best determined according to, (1) The site of non-union; (2) The gap in the bone; (3) The condition of the neighbouring joints. Non-union in the region of the neck can be successfully treated (*Fig.* 224): (1) By freshening the ends of the fragments, employing an intramedullary peg as an internal splint, and sowing in the fracture site small chips of bone obtained from the iliac crest (*Figs.* 225, 226); or (2) After thorough removal of sclerosed bone,

impacting the distal fragment into the proximal portion and obtaining fixation by wire or kangaroo tendon (*Fig.* 227).

Ununited fractures of the lower third of the humerus complicated by ankylosis of the elbow-joint are undoubtedly amongst the most difficult cases to treat. The reason for this lies in the real difficulty of providing adequate internal fixation of the fragments. This is more especially the case when the distal fragment is short, tapering, and brittle. The step-cut operation is generally not advisable ; but combined with Parham's metallic bands, the desired result can be obtained. Equally satisfactory results have followed the use of the intramedullary peg supplemented by a lateral graft or chips of iliac-crest bone (*Figs.* 228, 229, 230, 231).

Whichever operative measures are adopted, it is essential to fix the whole arm and chest in plaster-of-Paris at the time of operation. The arm is abducted to about a right angle, and the elbow is flexed, this being done to prevent any undue strain upon the fracture site. Fixation in this position is maintained for about eight weeks, at the end of which period the stitches are removed and the plaster cast is replaced by a suitable splint should the radiograms show that strong osseous union has occurred. In the majority of cases, however, it is safer to employ a plaster cast for a period of twelve to sixteen weeks. This need not interfere with the postoperative treatment, as the arm portion of the plaster-cast can be bivalved.

Tibia.—The following groups may be distinguished :—(1) *Fractures of the tibia with fibula intact* ; (2) *Fractures of the tibia with old fracture of fibula at opposite point.*

FIG. 232.—Tibia from *Case* 64. Non-union with 2-in. gap. Transverse fracture of fibula at opposite point. For result of grafting see *Fig.* 235.

FIG. 233.—Tibia from *Case* 73 before operation. Non-union with lateral displacement of upper fragment. For result of grafting see *Fig.* 234.

FIG. 234.—*Case* 73. Same as *Fig.* 233. Result 6 months after introduction of two massive grafts from opposite tibia. Grafts survived violent latent infection. Strong union.

Group 1.—There is usually very little displacement, and the rigid intact fibula prevents apposition of the fracture ends. The line of fracture is transverse or slightly oblique. The primary loss of osseous tissue is small, so that a single lateral graft suffices. The operative technique is similar to that carried out in the case of the ulna.

Group 2.—Whilst fracture of the tibia is of the large short-splinter type, followed by chronic osteomyelitis and necrosis with a resultant gap of ½ to 2 inches, that of the fibula

has been transverse (*Figs.* 232, 235). The displacement is always more marked in the tibia when the fibula has been simultaneously involved. There is frequently an angular displacement, the leg appearing to form a curve with a marked anterior concavity. In addition, some lateral displacement is generally present (*Fig.* 233). The lower fragment usually shows a certain degree of rotation on the long axis of the bone, resulting in internal or external displacement of the foot, and almost always a degree of pes equinus. In consequence of extensive scarring of overlying skin and also muscular injury, bone-grafting may be a very difficult procedure. It is beneficial in all such cases to carry out at a preliminary operation a complete excision of all superficial and deep scar-tissue at the site of non-union. About a month later the grafting operation is performed. It is advisable to insert two massive lateral grafts whenever possible (*Fig.* 234) in order to induce more rapid and entire replacement of the bony loss and to increase the strength of the resulting union. Unfortunately, re-fracture is by no means a rare occurrence, and for this reason there should be no undue haste in dispensing with the plaster casing, which should be worn for a period of six months at least subsequent to operation. For three months more the patient wears an external metal support.

FIG. 235.—*Case* 64. Same as *Fig.* 232. Result 6 months after grafting operation. Single massive graft. Strong union. Function of leg good.

Femur.—Whilst delayed union of the femur is frequent, non-union is of very rare occurrence. In fact, the diagnosis of non-union should not be made unless, after a prolonged trial (not less than twelve months) of conservative measures (Thomas splint, 'hammering and damming', ionization, faradism, and diathermy), there is no evidence of union either clinically or in radiograms.

The site of delayed union and non-union in all three cases of the present series was about the middle third of the shaft. When non-union does occur in this region it appears to be due to latent sepsis. Invariably the infection has spread to the knee-joint, whose movements become so limited that there is almost a fibrous ankylosis. In short, the function of the limb is considerably reduced.

FIG. 236.—Radius from *Case* 28. Early fracture of intramedullary peg. Strong union of graft with proximal fragment, but non-union with distal fragment. Strict and prolonged immobilization failed to bring about union.

The operation for non-union of the femur is at all times a serious one. Only one of the femur cases under review required operative interference, this consisting of freshening the fracture ends, complete excision of sclerosed bone and of intervening fibrous tissue, insertion of an intramedullary peg, and additional fixation by wire. The whole limb, including the pelvis, is put up in plaster-of-Paris for three weeks or a month, after which period a Thomas splint with extension is substituted.

Graft Fractures.—In the series of 83 cases subjected to the operation of transplantation of bone, 7 graft fractures occurred—3 in the ulna, 2 in the tibia, and 1 each in the radius and humerus. All but one were massive tibial grafts, and the fractures occurred at a late stage in 6 of the cases after osseous union between the host-bone and graft was complete. The exceptional case was an intramedullary peg, which at an early stage showed firm union with the proximal end of host-bone, but a false joint at the distal end (*Fig.* 236). The early fractures happen six to eight weeks after operation, and occur at one end exactly opposite the junction of the graft and the host-bone. Such a fracture may even occur inside a well-fitting plaster case, and is due to inadequate contact between the graft surface and the medullary tissue of the host-bone. If an intramedullary peg has been employed, the site of fracture becomes a typical non-union, the extremity of the fracture

becoming peg-shaped (*Fig.* 236). After the fracture is complete, little further absorption appears to take place. Strict immobilization after the fracture was discovered failed to bring about union in the case shown in *Fig.* 236.

FIG. 237.

FIG. 238.

FIG. 239.

FIG. 240.

Late fractures occur several months after the bone-grafting operation. Their site is almost always about the middle of the graft. The graft has been entirely successful, being firmly united at both ends, and the host-bone almost entirely replaced. The patient has probably returned to his civil occupation and as a result of some strain, the fracture is produced (*Figs.* 237–241). Many cases will reunite, although a prolonged period is required for the union to take place.

FIG. 237.—Ulna from *Case* 12. Traumatic or late graft fracture through middle of graft. Six months after successful graft operation.

FIG. 238.—*Case* 12. Same as *Fig.* 237. Result 8 months after accident—graft fracture strongly united. Well-marked callus thrown out.

FIG. 239.—Ulna from *Case* 4. Traumatic or late fracture through middle of graft. Six months after succes-ful graft operation.

FIG. 240.—*Case* 4. Same as *Fig.* 239. Result 10 months after accident—graft ununited, but no resultant disability.

FIG. 241.—Tibia from *Case* 62. Late graft fracture about middle of graft, occurred seventeen months after successful graft operation. Strong union resulted from second graft operation.

FIG. 241.

Table II.—Analysis of Results.

Bone	Number of Cases	Failures	Partial Successes	Complete Successes	Cases not requiring Operative Treatment
Ulna ..	36	0	0	30	6
Radius ..	26	1	1	20	4
Humerus ..	19	1	2	16	0
Tibia ..	15	1	0	10	4
Femur ..	3	0	0	1	2
Fibula ..	1	0	0	0	1
Total	100	3	3	77	17

SUMMARY AND CONCLUSIONS.

The series of cases studied was unselected and comprised 100 patients with ununited fractures due to war injuries. Of the 100, 83 required operative treatment. Of these, 70 were subjected to the operation of autogenous bone-grafting. In 67 (95·8 per cent) the grafting operations were successful, and 3 (4·2 per cent) were failures. The cause of failure was latent infection, and the graft was lost in consequence—in 2 of the cases with persistence of non-union. In the series of 83 operations there were 6 cases of latent infection. These six cases had been operated on previously, and all but one had had infection previously. The cause of infection depends upon the type of case rather than on the operative technique. It is probable that the general adoption of a two-stage operation would lower the percentage of infections. However, infection of a wound and a successful graft are not incompatible. In 61 cases the operation carried out has been a primary one, and in 24 cases unsuccessful attempts had been previously made by other surgeons.

Autogenous massive grafts obtained from the subcutaneous inner surface of the tibia have proved very successful, particularly in the ulna, radius, and tibia. They should be of good size—as large as the bone which is being replaced, and two to three times as long as the gap. The more the graft approximates in size to the bone it is to replace, the less liable it is to fracture. The medullary tissues would appear to be the main route along which new bone formation extends between the fragments of the host-bone. It is therefore advisable to include as much as possible of this tissue in any graft. Compact bone is required for strength to withstand the strain of function when union is complete. The presence or absence of periosteum on the graft does not appear to affect the vitality or growth of the graft. Internal fixation of the graft is most essential for a successful result, and depends to a considerable extent upon accurate suturing. Interrupted and 'looped' sutures of strong tanned catgut have been employed throughout the series almost without exception. The only adequate post-operative dressing is a plaster-of-Paris case applied at the time of operation. Absolute immobilization of the part involved is maintained for six weeks, during which period firm union should occur. The degree of union between the graft and host-bone can be determined by frequent radiographic examinations. During the transitional period adequate support (plaster or splint) of the graft is essential.

The bone-graft as usually employed in the intramedullary and inlay methods is too small, and not suited for ununited fractures due to war injuries.

In conclusion, my thanks are due to Mr. A. F. McConnochie, and also Dr. John W. L. Spence and Mr. J. McGill of the Radiological Department of the Ministry of Pensions Hospital, Craigleith, for the radiographic prints. The drawings illustrating the operative treatment are the work of Mr. J. T. Murray, to whom I am indebted for the great care expended in their preparation.

SYNOPSIS OF 100 CASES OF UNUNITED FRACTURES DUE TO

CASE	DATE OF WOUND AND WHEN HEALED	CAUSE AND PERIOD OF NON-UNION	BONE AND SITE OF NON-UNION	PREVIOUS OPERATIONS
Case 1.—C. A.	Sept. 1917 July, 1919	1 in. gap 25 months	L. ulna Middle third	Sequestrectomy and ev tion of abscess
Case 2.—A. B. *Figs.* 212, 219	Oct. 1917 April, 1918	3½ in. gap 17 months	R. ulna Lower half. Lower fragment of ulna remaining, 1¾ in.	Excision of scar and free tendons
Case 3.—R. B. *Figs.* 213, 220	Sept. 1918 Jan. 1919	1 in. gap 10 months	R. ulna Middle third	Suture of median nerve
Case 4.—J. B. *Figs.* 239, 240	April, 1918 Sept. 1918	2 in. gap 33 months	L. ulna Middle third	Suture of median nerve
Case 5.—G. C. *Figs.* 215, 216, 217	April, 1918 Aug. 1918	2 in. gap 30 months	L. ulna Upper fourth	Suture of ulnar nerve
Case 6.—J. D.	Oct. 1918 Feb. 1919	1 in. gap 16 months	L. ulna Middle third	Nil
Case 7.—S. McL.	June, 1918 Aug. 1918	3 in. gap 27 months	L. ulna Middle third	Removal of F. B.
Case 8.—A. M.	May, 1917 Sept. 1917	1 in. gap 25 months	R. ulna Middle third	Freeing of median nerv
Case 9.—N. S. *Figs.* 214, 221	April, 1915 Nov. 1917	1½ in. gap Sclerosis and plating 44 months	L. ulna Middle third	23 operations for remov dead bone, also platin ulna which was subsequ removed
Case 10.—G. T.	June, 1918 Sept. 1919	2½ in. gap 18 months	L. ulna Middle third	Nil
Case 11.—T. S.	Nov. 1918 Dec. 1918	1½ in. gap 13 months	L. ulna Upper fourth	Three preliminary sequ rectomies
Case 12.—J. J. *Figs.* 237, 238	Sept. 1915 Aug. 1916	1 in. gap Sclerosis and wiring 64 months	L. ulna Middle third	Sliding graft and fixatio wire. Wire subsequentl moved
Case 13.—J. A. *Figs.* 201, 218	Sept. 1918 Nov. 1918	1¼ in. gap 36 months	R. ulna Upper fourth	Sequestrectomy
Case 14.—T. M.	May, 1918 Aug. 1920	4 in. gap 41 months	L. ulna Middle third	Preliminary excision of s
Case 15.—A. T.	Sept. 1918 April, 1919	2½ in. gap 37 months	L. ulna Middle fourth	Nil
Case 16.—T. W.	Oct. 1917 Mar. 1918	2 in. gap 47 months	L. ulna Middle third	Nil
Case 17.—H. B. *Figs.* 194, 195	Sept. 1918 Jan. 1920	1¾ in. gap 41 months	L. ulna Middle third	Sequestrectomy. Bone-g June, 1920, which had removed on account of s
Case 18.—A. C.	Aug. 1918 Jan. 1919	Sclerosis and wiring 37 months	L. radius Junction lower third and upper two-thirds	Three operations (2 wirin ununited fracture

RIES, WITH END-RESULTS OF OPERATIVE TREATMENT.

TE AND TYPE OF OPERATION	RESULT	REMARKS
Oct. 1919 Tibial graft	Success	Operation delayed owing to persistent sinus and slow formation of sequestra. Complete range of pronation and supination. Resumed pre-war occupation
Mar. 1919 Tibial graft	Success	Exceptionally long graft required—6 inches. Fracture of graft detected Feb. 1920—strongly united Mar. 1921. Marked formation of callus. When the fracture was detected patient was not aware of anything wrong with forearm. Range of movement between ¾ complete supination and ⅔ complete pronation. Resumed employment as a joiner
July, 1919 Tibial graft	Success	Range of movement between complete supination and the mid-position. Employed as a rabbit trapper
Jan. 1921 Tibial graft	Success	Six months later fell and injured his arm. Fracture was exactly in middle of graft; no callus thrown out; no movement elicited at site of graft fracture. As patient felt arm just as strong as before the fracture, no further operation was performed. Range of movement between ¾ complete supination and 10° from the mid-position. Employed in a garage
Oct. 1920 ible tibial graft, eral and intra-medullary	Success	Forearm range of movement between ¾ complete supination and the mid-position. Employed as a caretaker, and contemplates farming in Canada, for which he is quite fit
Feb. 1920 Tibial graft	Success	Some superficial erosion of graft in early *x*-rays. Forearm range of movement between complete supination and ¾ complete pronation. Resumed pre-war occupation as a mason
Sept. 1920 Tibial graft	Success	Forearm range of movement between complete supination and 10° of pronation from the mid-position. Employed as a postman
June, 1919 Tibial graft	Success	Forearm range of movement between complete supination and the mid-position. Employed as a clerk
Dec. 1919 Tibial graft	Success	Forearm range of movement between complete supination and ⅔ complete pronation. Unemployed. Does not think he will be fit for pre-war occupation as a miner
Dec. 1919 Tibial graft	Success	Forearm range of movement between complete supination and 10° pronation from the mid-position. Employed as an engineman
Dec. 1919 Tibial graft	Success	Forearm range of movement between ⅔ complete supination and the mid-position. Employed as a postman and finds his arm as strong as previously
Jan. 1921 Tibial graft	Success	Injured reconstructed forearm six months after operation—fracture of graft, which was found to be strongly united three months later. Employed as a miner
Sept. 1921 Tibial graft	Success	Forearm range of movement between complete supination and 10° of the mid-position. Discharged from hospital to commence out-patient treatment
Oct. 1921 Tibial graft	Success	Forearm range of movement between complete supination and ⅔ complete pronation
Oct. 1921 Tibial graft	Success	Also had fracture of radius at same level, but strongly united with fair alinement. Forearm range of movement between ¾ complete pronation. Still receiving massage and electricity
Sept. 1921 Tibial graft	Success	Fit to resume employment in brick works. Forearm range of movement between ¾ complete supination and the mid-position. Still receiving massage and electricity
Feb. 1922 Tibial graft	Success	Severe latent infection followed second bone-graft—both forearm and leg—no damage to graft or tibia resulted. Still receiving massage and electricity
Sept. 1921 Tibial graft	Success	Forearm range of movement between ⅔ complete pronation and ¾ complete supination. Still unemployed

Continued on next page

SYNOPSIS OF 100 CASES OF UNUNITED FRACTURES DUE TO

Case	Date of Wound and when Healed	Cause and Period of Non-union	Bone and Site of Non-union	Previous Operations
Case 19.—W. B. *Figs.* 204, 211	July, 1917 May, 1918	3 in. gap 28 months	L. radius Middle third	Freeing of median nerve
Case 20.—W. D. *Fig.* 209	Oct. 1917 Feb. 1918	1¼ in. gap 16 months	L. radius Middle third	Nil
Case 21.—R. M.	Aug. 1917 Feb. 1918	Latent sepsis and sclerosis 31 months	R. radius Lower third	Freeing of flexor mu Suture of median nerve
Case 22.—A. M.	Aug. 1918 Mar. 1919	1 in. gap 15 months	L. radius Junction upper and middle thirds	Removal of F.B.
Case 23.—A. M.	Mar. 1918 July, 1918	2½ in. gap 12 months	L. radius Junction upper and middle thirds	Sequestrectomy
Case 24.—A. M.	Oct. 1917 Dec. 1917	¾ in. gap 17 months	L. radius Junction middle and lower thirds	Nil
Case 25.—A. P.	June, 1918 Nov. 1918	3½ in. gap 13 months	L. radius Middle third	Freeing extensor muscle forearm. Transplant
Case 26.—J. S.	Oct. 1917 Dec. 1917	¼ in. gap Sclerosis and wiring 12 months	L. radius Junction upper and middle thirds	Wiring of fracture
Case 27.—R. S. *Fig.* 207	April, 1917 Dec. 1917	½ in. gap Sclerosis 36 months	R. radius Junction lower fifth and upper four-fifths	Excision of scar and corre of radial deviation of by plaster-of-Paris
Case 28.—T. C. *Fig.* 236	Sept. 1917 May, 1918	1½ in. gap 30 months	R. radius Lower fifth	Nil
Case 29.—J. C.	April, 1917 Dec. 1918	1½ in. gap 31 months	R. radius Through lower third	Nil
Case 30.—H. C.	June, 1915 Feb. 1918	1¼ in. gap 45 months	L. radius Lower third	Suture of median nerv lower third of forearm
Case 31.—A. M.	April, 1917 Sept. 1918	½ in. gap 20 months	L. radius Lower fourth	Nil
Case 32.—R. McK.	Sept. 1918 Jan. 1919	1¾ in. gap 10 months	R. radius Junction lower and middle thirds	Freeing of median nerve extensor muscles of fore
Case 33.—P. G.	April, 1915 Oct. 1918	Sclerosis ¼ in. gap 55 months	L. radius Middle third	Nil
Case 34.—J. K. *Fig.* 206	May, 1917 Aug. 1917	Sclerosis No gap 29 months	R. radius Junction lower and middle thirds	Nil
Case 35.—D. D.	Aug. 1918 April, 1919	Sclerosis ½ in. gap 40 months	L. radius Junction lower and middle thirds	Plating of radius. Plate sequently removed a union resulted

ES, WITH END-RESULTS OF OPERATIVE TREATMENT—*continued.*

ND TYPE OF ERATION	RESULT	REMARKS
v. 1919 ial graft	Success	Extensive removal of sclerosed bone necessitated graft 6 in. long. Forearm movements between mid-position and $\frac{2}{3}$ complete pronation. Employed as a clerk
b. 1919 ial graft	Success	Forearm range of movement between $\frac{3}{4}$ complete supination and $\frac{2}{3}$ complete pronation. Able to resume pre-war employment as a printer
r. 1920 ial graft	Success	Forearm range of movement from mid-position to 15° pronation. Employed as a telephone operator
v. 1919 ial graft	Success	Forearm held almost in complete supination. Few degrees of movement possible. Almost complete canalization of graft
r. 1919 graft from dius	Success	Forearm range of movement between complete supination to 10° from the mid-position. Employed as a clerk
r. 1919 graft from dius	Success	Ulna was fractured at opposite point and strongly united without operation. Forearm range of movement between $\frac{3}{4}$ complete supination and the mid-position. Resumed pre-war occupation as a miner
y. 1919 ial graft	Success	Septic dermatitis of arm so persistent that amputation was advised. This condition, however, was cured by lipoid paraffin. Forearm range of movement between complete pronation and the mid-position. Resumed pre-war occupation as railway clerk
t. 1918 ial graft	Success	Forearm range of movement between complete supination and $\frac{2}{3}$ complete pronation. Complains of pain in the lower end of the ulna, this being due to subluxation which may have resulted from attempting heavy work as a labourer
ril, 1920 dullary tibial graft	Success	This type of graft employed on account of inadequate coverings for a lateral graft. Employed in an office
r. 1920 dullary tibial peg	Partial success	Upper end strongly united; lower end failed to unite. This type of graft was employed on account of inadequate coverings for a lateral graft. Training as a picture frame maker
l operation v. 1919	—	—
r. 1919 ng of ulna ($1\frac{5}{8}$ oved), wiring s and ulna	Failure	Radial deviation of hand corrected, and consequently able to work as a labourer. Almost a new wrist-joint formed at site of ununited fractures. Strong flexion and extension present
c. 1918 peration at- , but im- owing to nage	—	Radial deviation of hand very marked. Posterior subluxation of lower end of ulna. Unable to resume work as miner, but found suitable employment
y, 1919 ial graft	Success	Forearm range of movement between $\frac{3}{4}$ complete supination and 10° of pronation from the mid-position. Unable to resume pre-war occupation in pits, but has secured suitable work
n inadvisable to mal-union pposite point v. 1919	—	Quite a serviceable arm, although not fit for pre-war occupation as a tailor
ithout opera- let awaiting n to hospital t. 1919	—	Forearm range of movement between complete supination and $\frac{1}{4}$ complete pronation. Also had posterior subluxation of the lower end of the ulna. Employed as a labourer
c. 1921 ial graft	Success	Preliminary operation for removal of plate and correction of radial deviation of hand. Forearm range of movement between $\frac{2}{3}$ complete supination and $\frac{2}{3}$ complete pronation. Still receiving massage and electricity

Continued on next page

SYNOPSIS OF 100 CASES OF UNUNITED FRACTURES DUE TO

CASE	DATE OF WOUND AND WHEN HEALED	CAUSE AND PERIOD OF NON-UNION	BONE AND SITE OF NON-UNION	PREVIOUS OPERATIO
Case 36.—J. M.	Nov. 1915 Feb. 1919	1 in. gap 72 months	L. radius Junction lower and middle thirds	Bone-graft in another which was subsequ moved owing to Excision of scar
Case 37.—W. H.	April, 1917 Feb. 1919	Sclerosis 55 months	L. radius Junction lower fourth with remainder	Sequestrectomies. operation; removal as no union resulted
Case 38.—C. McG.	Aug. 1917 Oct. 1917	1½ in. gap 23 months	L. radius Middle third	Nil
Case 39.—G. G. *Figs.* 202, 203, 205, 208	Sept. 1918 Dec. 1918	1¼ in. gap 11 months	R. radius Lower third	Nil
Case 40.—D. G.	May, 1918 Nov. 1918	2½ in. gap 20 months	L. radius Middle third	Sequestrectomy
Case 41.—J. B. *Fig.* 210	Oct. 1918 Dec. 1918	1½ in. gap 15 months	L. radius Junction lower and middle thirds	Nil
Case 42.—J. B.	Nov. 1916 Nov. 1917	Sclerosis ½ in. gap and plating 34 months	L. radius Middle third	Plating operation. R of plate. Freeing o nerve
Case 43.—A. N.	July, 1916 Mar. 1917	1¾ in. gap Marked sclerosis 69 months	R. ulna Middle third	Sequestrectomy
Case 44.—J. C.	Aug. 1917 Dec. 1917	2½ in. gap Displacement upper fragment 56 months	L. ulna Upper third	Suture of ulnar nerv cision of scar
Case 45.—J. McI.	April, 1917 June, 1917	1¼ in. gap 58 months	L. ulna Junction upper and middle thirds	Excision of scar
Case 46.—J. C.	Aug. 1917 Nov. 1917	1¾ in. gap 14 months	R. ulna Junction lower and middle thirds	Nil
Case 47.—L. M.	April, 1917 Oct. 1917	1 in. gap Still ununited	L. ulna Junction lower and middle thirds	Sequestrectomies. Fre extensor tendons in f
Case 48.—P. C.	Feb. 1918 Nov. 1918	½ in. gap Still ununited	L. ulna Junction lower and middle thirds	Nil
Case 49.—D. S.	Dec. 1917 Sept. 1918	3 in. gap Synostosis between upper end of ulna and opposite point of radius	R. ulna Upper 3 in. with olecranon process missing	Nil
Case 50.—A. S.	Oct. 1915 Sept. 1916	Sclerosis ¼ in. gap	L. ulna Lower fifth	Nil
Case 51.—E. B.	May, 1918 Dec. 1918	½ in. gap Still ununited	L. ulna Lower fourth	Suture of median nerv questrectomy of ulna

URIES, WITH END-RESULTS OF OPERATIVE TREATMENT—*continued.*

DATE AND TYPE OF OPERATION	RESULT	REMARKS
Nov. 1921 Tibial graft	Success	Forearm range of movement between $\frac{2}{3}$ complete supination and $\frac{2}{3}$ complete pronation. Is receiving massage and electrical treatment
Nov. 1921 Tibial graft	Success	Still in hospital. Forearm range of movement between complete pronation and $\frac{2}{3}$ complete supination
July, 1919 Tibial graft	Success	Forearm range of movement between $\frac{3}{4}$ complete supination and 10° of pronation from the mid-position. Employed as a labourer, and when working feels pain in inferior radio-ulnar joint
Aug. 1919 ial graft. Marked dial deviation of nd corrected by gthening of mus-es	Success	Forearm range of movement between complete supination and the mid-position. Employed as a glass-blower
Jan. 1920 Tibial graft	Success	Forearm held in position of $\frac{3}{4}$ complete supination. Very good grip. Resumed pre-war occupation in paper mill
Jan. 1920 Tibial graft	Success	Forearm range of movement between complete supination and $\frac{3}{4}$ complete pronation. Employed as a traveller
Sept. 1919 Tibial graft	Success	Forearm range of movement between complete supination and the mid-position. Employed as a motor driver
April, 1922 Tibial graft	Success	Still under treatment
April, 1922 ouble tibial graft	Success	Still under treatment for ulnar nerve paralysis. Employed as a caretaker
Feb. 1922 Tibial graft	Success	Still under treatment
Oct. 1918 Tibial graft	Success	Employed as a clerk
No operation	—	As site of fracture immediately above lower end of ulna, grafting operation considered inadvisable. Employed as a printer
No operation	—	Operation not advised owing to site of non-union. Resumed pre-war employment as a miner, and can lift a 56 lb. weight with injured arm
No operation	—	As range of all movements, voluntary power of muscles, and stability of joint all good, operation not advised
No operation	—	Operation not advised as patient suffered little disability from fracture
No operation	—	Operation not advised as site of fracture low down

Continued on next page

SYNOPSIS OF 100 CASES OF UNUNITED FRACTURES DUE TO W

Case	Date of Wound and when Healed	Cause and Period of Non-union	Bone and Site of Non-union	Previous Operations
Case 52.—A. M.	Aug. 1918 Mar. 1919	1¾ in. gap 44 months	L. ulna Junction upper fourth and lower three-fourths	Bone-graft of radius
Case 53.—R. T.	Aug. 1918 Jan. 1920	2½ in. gap 17 months	R. ulna Middle third	Sequestrectomy
Case 54.—D. W.	April, 1917 April, 1918	Sclerosis and latent sepsis 58 months	R. femur Middle third	Sequestrectomies. Several a scesses.
Case 55.—G. D.	April, 1917 Aug. 1919	Sclerosis ¾ in. gap	R. tibia Junction lower and middle thirds	Nil
Case 56.—J. B.	April, 1918 Mar. 1919	2 in. gap 11 months	R. tibia Middle third	Sequestrectomies. Fibu bone-graft, excision of s in other hospitals
Case 57.—W. C.	Oct. 1918 June, 1919	Sclerosis and displacement 17 months	R. tibia Middle third	Nil
Case 58.—P. S.	Aug. 1917 Sept. 1918	¾ in. gap 21 months	R. tibia Middle third	Nil
Case 59.—B. W.	May, 1915 Jan. 1916	Sclerosis Still ununited	L. tibia Middle third	Nil
Case 60.—J. McL.	April, 1917 June, 1920	Sclerosis 38 months	L. tibia Middle third	Nil
Case 61.—T. H.	Sept. 1918 Mar. 1921	2 in. gap 39 months	L. tibia Junction middle and upper thirds	Excision of skin scar. Cica and scar-tissue
Case 62.—H. K. A. *Fig.* 241	May, 1917 April, 1918	2 in. gap 33 months	R. tibia Junction upper and middle thirds	Excision of skin. Cicatrix scar-tissue
Case 63.—J. G.	May, 1915 June, 1919	1¾ in. gap 62 months	R. tibia Through middle third	Excision of wound. Plati tibia, removal of plate
Case 64.—L. F. *Figs.* 232, 235	Oct. 1917 June, 1919	2½ in. gap 22 months	L. tibia Middle third	Sequestrectomy
Case 65.—C. R.	Mar. 1918 Nov. 1918	Sclerosis and displacement 51 months	L. humerus Junction of lower and middle thirds	Exploration of musculosp nerve. Transplantation tendons
Case 66.—J. McK.	Mar. 1918 Aug. 1918	Sclerosis 24 months	L. humerus Junction lower fifth and upper four-fifths	Suture of musculospiral ne Suture of ulnar nerve and bo graft of humerus wnich subsequently removed. M culospiral nerve re-suture
Case 67.—H. B. *Fig.* 226	Oct. 1918 Mar. 1919	Sclerosis 12 months	R. humerus Anatomical neck	Unsuccessful bone-graft other hospital
Case 68.—A. R. *Figs.* 224, 225	Oct. 1918 June 1919,	Sclerosis 16 months	R. humerus Surgical neck	Sequestrectomy and exci of sinus

IES, WITH END-RESULTS OF OPERATIVE TREATMENT—*continued.*

AND TYPE OF OPERATION	RESULT	REMARKS
pril, 1922 ibial graft	—	Still in hospital. Almost complete canalization of radius graft
Jan. 1920 ibial graft	Success	Forearm range of movement between complete supination and ¾ complete pronation. Resumed employment in gas meter works.
ted without peration Feb. 1922	—	Owing to the persistence of latent sepsis, the question of operation could never be considered. Treatment consisted of: (1) Extension by Thomas's splint; (2) 'Hammering and damming'; (3) Calcium ionization and calcium salts internally; (3) Endocrine gland tablets; (4) Faradism
ted without peration	—	Osteogenesis was delayed by sepsis
Mar. 1919 ibial graft	Failure	Graft fixed by wire: partial death of graft, this portion removed along with wires. Non-union again resulted
Mar. 1920 ibial graft	Success	Unemployed. Still wears a steel support, as he is afraid to bear his whole weight on reconstructed limb
May, 1919 tibial graft	Success	Would have been able to resume pre-war occupation as a miner but for 3 in. shortening of the leg as a result of fracture of the femur. Wears a high boot. Employed as a motor-man in the mines
operation	—	Refused treatment
ed without peration	Success	'Hammer and dam' treatment
Dec. 1921 tibial graft	Success	Portion of host tibia was utilized when filling up gap between the two grafts. Although still under treatment, firm union has resulted
Feb. 1920 raft (Bangour) Oct. 1921 graft (Craig-	Success	In the case of the first graft, both ends strongly united; fracture over upper end occurred July, 1921, which did not unite, and necessitated second graft. All evidence points to very satisfactory result
July, 1920 ibial graft	Success	Walks without a caliper
ng. 1919 ibial graft	Success	Able to resume his work as a farmer. Does not require to wear a caliper. Required small skin-graft for necrosis of scarred skin
une, 1922 g operation of us	Success	Wound healed. Firm union. Still under treatment
Mar. 1920 aft of humer- ntramedullary peg, and chip iliac crest	Success	Resumed farming in Canada
Oct. 1919 edullary peg, ng of fragments	Success	Arm can be fully and strongly abducted to angle 70°. Good firm union at site of fracture. Radial movements from extension practically normal. Flexion at shoulder almost to a right angle. Hopes to resume work as a riveter
Feb. 1920 edullary tibial squaring of nts, and chips iliac crest	Success	Necrosis of iliac chips and consequent sinuses. Ultimate result of graft satisfactory. Abduction at shoulder to angle 60°, flexion almost to a right angle. Works on a farm

Continued on next page

SYNOPSIS OF 100 CASES OF UNUNITED FRACTURES DUE TO

Case	Date of Wound and when Healed	Cause and Period of Non-union	Bone and Site of Non-union	Previous Operations
Case 69.—S. D.	Sept. 1918 Oct. 1919	2 in. gap	R. fibula Upper and middle third	Nil
Case 70.—J. E.	Nov. 1918 Mar. 1921	Sclerosis 28 months	L. femur Lower and middle third	Sequestrectomies
Case 71.—D. H.	April, 1918 July, 1918	Sclerosis 1½ in. gap 17 months	L. humerus Lower third	Nil
Case 72.—J. A.	Sept. 1915 Nov. 1916	Sclerosis ¼ in. gap 35 months	L. humerus Lower fourth and upper three-fourths	Two bone-grafts in S land, and sequestre Also inlay bone-graft fractured and had removed
Case 73.—T. McC. *Figs.* 233, 234	May, 1915 Dec. 1920	Sclerosis and displacement 76 months	R. tibia Middle third	Sequestrectomies
Case 74.—J. R.	Feb. 1918 May, 1918	2½ in. gap 17 months	R. tibia Middle third	Sequestrectomies
Case 75.—N. McD.	Aug. 1917 Sept. 1919	Sclerosis and displacement 42 months	R. tibia Lower third	Two bone-grafts in hospitals which were successful. Removal from graft
Case 76.—J. G.	Sept. 1917 April, 1918	Latent sepsis 11 months	R. tibia Upper third	Abscess in leg opened
Case 77.—W. H.	Oct. 1916 Mar. 1917	Lower third of humerus missing, complicated by flail elbow 27 months	R. humerus Lower third	Transplantation of te Tibial bone-graft in a hospital which had removed
Case 78.—R. G.	Oct. 1916 July, 1917	Articular surface of humerus absent, part of olecranon process absent, complicated by flail elbow 28 months	R. humerus Lower third	Tibial bone-graft in a hospital which had removed
Case 79.—T. W.	Aug. 1916 Nov. 1919	Sclerosis 53 months	R. humerus Middle of lower third	Sequestrectomies. St operation for humeru successful
Case 80.—T. W.	Aug. 1917 April, 1918	Sclerosis 27 months	R. humerus Junction of lower and middle thirds	Sequestrectomies: wir humerus
Case 81.—J. C. *Figs.* 222, 223	Aug. 1918 Mar. 1919	Sclerosis and displacement 9 months	R. humerus Middle third	Transplantation of tend drop-wrist
Case 82.—J. B.	April, 1917 Nov. 1917	Displacement 1½ in. gap 29 months	R. humerus Middle third	Tibial bone-graft in a hospital, removal of owing to sepsis

RIES, WITH END-RESULTS OF OPERATIVE TREATMENT—*continued*.

E AND TYPE OF OPERATION	RESULT	REMARKS
o operation	—	Operation unnecessary as no disability complained of. Employed as a labourer
o operation	Success	Femur first united Mar. 1920; refractured by slipping on floor, June, 1920, also causing wound to break down. Treatment consisted of: (1) Extension by Thomas's splint; (2) 'Hammer and dam'; (3) Calcium ionization and calcium salts internally; (4) Endocrine gland tablets; (5) Diathermy; (6) Faradism. Fracture started to reunite definitely middle of April, 1921, and was firmly united by Nov. 1921. Employed as a lawyer
Sept. 1919 ng operation of humerus	Success	Ankylosis of elbow and wrist. Bone-marrow of humerus similar in appearance to that in leukæmia. Employed as a clerk
Aug. 1918 ng operation of humerus	Success	Had fibrous ankylosis of elbow, and required transplantation operation for drop-wrist. Employed as a clerk
Sept. 1921 ble tibial graft	Success	Marked recrudescence of latent sepsis; notwithstanding this, grafts did not die, and strong union resulted
July, 1919 Tibial graft	Success	Graft was fixed by wire. Employed as a miner
Feb. 1921 ble tibial graft	Success	Was discharged to out-patient treatment and allowed to bear weight on leg too early, with partial fracture of one graft. Slight recrudescence of latent sepsis occurred after graft operation. This did not affect ultimate strong union. Employed as a fisherman
ited without operation Aug. 1918	—	Fracture was transverse with very slight loss of bone. By means of Bier's congestion and 'hammer and dam' treatment, good union resulted. Employed as a miner
Jan. 1919 g of humerus, s, and ulna, in-ction of chips iliac crest	Partial success	Increased control of flail joint, and with aid of splint patient is able to work as an electrical engineer
Feb. 1919 rodesis of elbow	Success	Able to work as a labourer. Has several degrees strong flexion and extension of elbow
Jan. 1921 medullary tibial lateral tibial and chips from crest	Partial success	Absorption of intramedullary graft, union of lateral graft to lower end of humerus, non-union of graft to upper end due to recrudescence of latent sepsis. Latent sepsis still present
Nov. 1919 ping operation er humerus	Failure. Diabetes.	No union resulted. Ankylosis of elbow. General health unsatisfactory owing to diabetes. Marked osteoporosis of lower end of humerus, which fractured when stepping operation was carried out
May, 1919 ping operation er humerus	Success	Elbow range of movement from angle 160° to angle 170°. Resumed pre-war occupation as a postman
Sept. 1919 ping operation merus, and re-l of wire	Success	Elbow range of movement between angle 150° and angle 90°

Continued on next page

SYNOPSIS OF 100 CASES OF UNUNITED FRACTURES DUE TO

Case	Date of Wound and when Healed	Cause and Period of Non-union	Bone and Site of Non-union	Previous Operation
Case 83.—G. T.	Aug. 1916 Sept. 1917	Sclerosis 38 months	R. humerus Junction of lower and middle thirds	Nine operations for rem dead bone and metal Squaring and rawi humerus and fixati aluminium wire whi subsequently to be re
Case 84.—A. N.	Mar. 1918 May, 1919	1¼ in. gap Displacement 24 months	R. humerus Junction of lower and middle thirds	Sequestrectomies. transplantation for dro
Case 85.—T. S. C.	Oct. 1918 Nov. 1918	Sclerosis and latent sepsis 19 months	L. femur Junction lower and middle thirds	Nil
Case 86.—J. B. C.	Sept. 1918 Jan. 1919	— 20 months	R. radius Through middle third	Tibial bone-graft whic been applied with fra of host-bone not in alinement
Case 87.—J. V. *Fig.* 227	April, 1918 April, 1920	Sclerosis ¼ in. gap 42 months	R. humerus Surgical neck	Sequestrectomies
Case 88.—G. B.	Sept. 1918 Oct. 1919	Whole of shaft missing 43 months	L. humerus Lower two-fifths	Sequestrectomies. Tibial graft in other hospital was ultimately removed to sepsis. Several sh operations
Case 89.—W. McD.	Oct. 1918 Aug. 1919	1½ in. gap Displacement 40 months	R. humerus Junction lower and middle thirds	Nil
Case 90.—J. H.	Aug. 1918 Feb. 1919	2 in. gap Sclerosis 45 months	R. ulna Junction lower and middle thirds	Freeing of ulnar nerv lengthening of flexor t for contracted fingers. cision of scar
Case 91.—T. T.	April, 1915 Dec. 1915	Displacement and sclerosis 85 months	R. humerus Junction of lower and middle thirds	Transplantation of tend
Case 92.—J. H.	July, 1916 Mar. 1918	1¾ in. gap	L. ulna Junction lower and middle thirds	Freeing of ulnar nerve
Case 93.—T. B. *Figs.* 230, 231	Aug. 1918 May, 1919	Sclerosis and sepsis 19 months	L. humerus Lower and middle thirds	Nil
Case 94.—W. H. *Figs.* 228, 229	April, 1918 Feb. 1919	¾ in. gap Sclerosis 27 months	L. humerus Junction of lower fourth and upper three-fourths	Suture of musculospiral Wire operation. transplantation. Bon
Case 95.—J. McK.	Feb. 1918 (Accident)	Ununited fracture of styloid process of ulna 22 months	L. ulna Styloid process	Nil

URIES, WITH END-RESULTS OF OPERATIVE TREATMENT—*continued.*

ATE AND TYPE OF OPERATION	RESULT	REMARKS
Oct. 1919 pping operation for for humerus	Success	On examination three years later a very satisfactory result was found. Employed as a haulage engineman in the mines. Finds no disability from his arm. Ankylosis of elbow
Mar. 1920 Tibial graft	Success	Strong union with good alinement
May, 1920 amedullary tibial ft, chips from c crest, and ring	Success	Walks without a caliper
May, 1920 vious graft re-ved and new tibial ft inserted with lius fragments in per alinement	Success	First graft had been inserted with upper fragment of radius completely supinated and lower fragment completely pronated, so that forearm movements reduced to nil. By means of fresh graft and correction of alinement good forearm movements obtained
Oct. 1921 epping operation	Success	Abduction of shoulder to angle 70°. 10° of external and internal rotation. Elbow completely ankylosed angle 120°. Forearm fixed in mid-position. Strong union resulted. He is satisfied that he can return to his pre-war occupation on the railway
April, 1922 ble tibial graft, ed by Parham's tallic bands	Success	Still under treatment. Most violent recrudescence of latent infection occurred in the axilla and left flank. Operation scar and graft bed remained intact.
Feb. 1922 pping operation for merus, fixed by rham's metallic nds	Success	Still under treatment. Ankylosis of elbow made stepping operation more difficult. Strong union has resulted
May, 1922 Tibial graft	Success	Still under treatment
May, 1922 pping operation for merus, fixed by rham's metallic nds	Success	Still under treatment
—	—	Graft operation could not be carried out as patient had to return to Canada
Mar. 1920 amedullary tibial ft with chips n iliac crest	Success	Elbow movement from angle 160° to angle 80°. This case is remarkable for the large amount of callus thrown out after bone-graft operation. Strong union has resulted. Resumed farming work in Canada
July, 1920 ble tibial intra-dullary and lateral ne-graft	Success	Elbow range of movement from angle 170° to a right angle. Complete absorption of intramedullary graft; although lateral graft fractured partially, very strong union resulted. Training in commercial work
Dec. 1919 ng graft of ulna. ening of lax cap-ar ligament	Success	Employed as a commercial traveller. This operation was performed for recurrent anterior dislocation of the lower end of the ulna complicated by ununited fracture of the styloid process of the ulna

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SYNOPSIS OF 100 CASES OF UNUNITED FRACTURES DUE TO W

CASE	DATE OF WOUND AND WHEN HEALED	CAUSE AND PERIOD OF NON-UNION	BONE AND SITE OF NON-UNION	PREVIOUS OPERATIONS
Case 96.—J. H.	Mar. 1917 Jan. 1918	1¾ in. gap 37 months	R. ulna Junction of lower and middle thirds	Nil
Case 97.—C. S.	Sept. 1918 May, 1919	1¼ in. gap 44 months	L. ulna Through upper third	Sequestrectomies. Suture ulnar nerve
Case 98.—A. C.	May, 1915 Nov. 1917	2 in. gap 85 months	L. ulna Lower third	Sequestrectomies
Case 99.—G. M.	June, 1917 Mar. 1919	1½ in. gap 60 months	L. ulna Lower third	Plating of ulna
Case 100.—C. A.	Jan. 1920 (Propeller accident)	Displacement 3 months	R. styloid process of ulna, complicated by fibrous union junction lower and middle thirds of radius, and anterior dislocation lower end of ulna	Attempted reduction u anæsthetic in another pital ; failure

IES, WITH END-RESULTS OF OPERATIVE TREATMENT—*continued.*

AND TYPE OF OPERATION	RESULT	REMARKS
April, 1920 Tibial graft	Success	Forearm range of movement between complete supination and complete pronation
May, 1922 Tibial graft	Success	Marked impairment of pronation and supination
June, 1922 Tibial graft	Success	Still under treatment
June, 1922 Tibial graft	Success	Still under treatment
April, 1920 val of styloid ess of ulna. Re- ion of disloca- Excision of us union of s	Success	Remained in army

SHORT NOTES OF RARE OR OBSCURE CASES.

METASTATIC MELANOMA OF SCAPULA.

By F. D. CAIRNS, Gibraltar.

The following case seems worthy of report in view of the very prolonged interval between the appearance of a primary growth and its subsequent dissemination. Eighteen years' freedom from dissemination would be regarded as a remarkable interval in tumours of the most slender claim to malignant character, so that occurring as it did in a melanotic growth of the eye—a tumour usually regarded as highly virulent in its type—that interval is doubly noteworthy. Further, the site of the metastatic deposit is a somewhat unusual one, namely in the scapula, whose immunity from secondary growths was noted by Von Recklinghausen in his researches on metastasis in bone.

G. J., age 59, insurance agent. The patient was admitted under the care of Professor Alexis Thomson for a swelling over the right shoulder-blade. Attention was first called to the condition five months ago, when his friends remarked that he was becoming round-shouldered, an appearance which had progressed gradually, whilst the movements of his arm had latterly become impaired. The patient was conscious of no circumstance which could be held responsible for the appearance of the swelling, and beyond the altered shape of his shoulder and the restricted range of movements at the shoulder-joint, he had no complaint.

Eighteen years ago he suffered from loss of vision in his left eye. Examination at that time showed this to be due to a tumour in the eye, and this was removed by Sir George Berry. During the last twelve months he has had varying degrees of difficulty in retaining the artificial eye in the socket, the latter apparently beginning to fill up, and for the last four weeks it has been quite impossible to retain the artificial eye in position. His general health during the last eighteen years has been entirely satisfactory, and his family history does not provide any relevant fact.

Local Examination.—The swelling was rounded, the size and shape of a lemon, firm and elastic, projecting from and fixed to the infraspinous portion of the right scapula. It moved with scapular movements, and the skin was movable over it. It was neither the seat of pain, nor was it tender to touch. There was no distention of the overlying veins, nor were the axillary glands palpably enlarged. Movements at the shoulder-joint were performed painlessly, but were restricted in range, particularly as regards abduction, by the bulk of the swelling. The tissues occupying the socket of the left eye were unduly prominent, and palpation showed them to be the seat of a firm elastic growth, presumably a local recurrence of his previous tumour. General examination showed no further signs of swellings, and the liver was apparently normal in size and function. The urine was pale in colour and free from albumin and melanin.

Operation.—This was performed by Professor Thomson, and the scapula removed. Initially the subscapular artery was exposed by an axillary incision and ligated as an aid in dealing with the hæmorrhage during the subsequent proceedings. The size of the artery in this case, however, hardly warranted the expenditure of time involved, and it is doubtful if the excision of the bone was in any way facilitated by it. It is open to question, therefore, whether or not the preliminary ligation of the subscapular trunk is to be recommended, as suggested by Watson Cheyne.

Appearance of Tumour.—The lower half of the infraspinous fossa presents a rounded tumour the size of an orange (*Fig.* 242). It does not extend up to the axillary border, but is continuous round the vertebral border, with a flattened nodular extension which lies in the corresponding position of the venter scapulæ. Firm in consistence, it is mottled in colour, black areas intermingling with white. The bone between these two segments of tumour is destroyed, and its place taken by tumour tissue, which effects continuity between them. Section shows the character of a melanotic tumour, bluish-black areas scattered through a cerebriform matrix.

Fig. 242.—Scapula with metastatic melanoma.

Microscopic Examination. — The field is almost wholly cellular, though here and there bands of young connective tissue traverse it, and divide it into more or less separate areas. Pigment, varying in colour from golden-brown where it is scanty in amount to inky-black where it is abundant, is scattered irregularly through the section. The bands of connective tissue have a more liberal supply of pigment than the more cellular areas. The cellular content falls roughly into three fields: (1) Areas of cells definitely spindle-shaped running in bundles or loosely separated; (2) Round cells loosely approximate with no apparent ground-work, immature blood-vessels, and the characters of a small round-cell sarcoma; (3) Groups of rounded cells massed together in an alveolar-like arrangement, and contained by an investment of large spindle-shaped cells. (*Fig.* 243.)

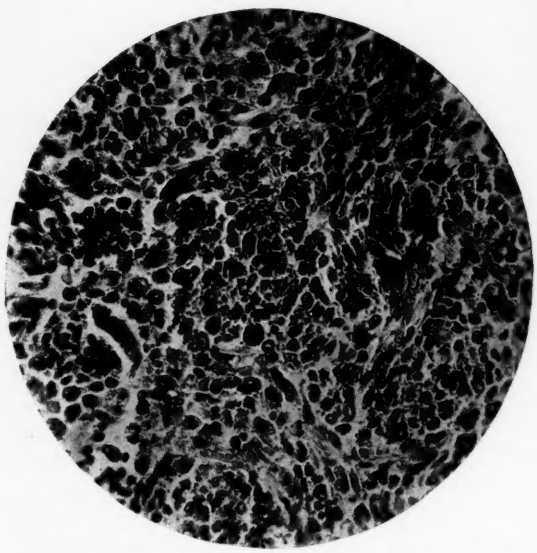

Fig. 243.—Metastatic melanoma of scapula. Area of small round cells.

The fact that the young septa are richer in their supply of pigment than other areas suggests that the more mature the cell, the greater its faculty for the manufacture of colouring matter. The spindle cells are of all types, varying from the frank cell to the attenuated unit disappearing in the fibres of a connective-tissue bundle. The cell protoplasm stains faintly and the nucleus is prominent, ovoid, and clear. Mitotic figures are common. In many cells golden-brown particles of melanin are to be seen, either limited to the nuclear poles or occupying and obscuring

the whole cell body. Blood-vessels are immature and spaced midst the bundles of cells.

Round cells of all variations in size occur in groups presenting the features of a round-celled sarcoma. In many cases these cells are multinucleated and show active mitosis. Pigment occurs to some extent in the cells of these particular areas, but is less abundant than in the areas of spindle-shaped cells.

The groups of cells massed together into an alveolar-like arrangement are practically free from pigment. The cells are small and rounded and, apart from their massed appearance, do not resemble the spheroidal cells which compose the tumours commonly regarded as melanocarcinomata.

PATHOLOGY.—Both to the naked eye and under the microscope the tumour displays the characteristics of a melanotic sarcoma which clinically and pathologically is secondary to the recurrence in the eye. The pathological classification is that of a mixed-cell melanotic sarcoma, but the occurrence of groups of cells in an alveolar-like arrangement may not be without significance in pointing to the genetically identical relationship which is claimed by some authorities for melanocarcinoma and melanosarcoma. Melanotic tumours arising in relation to the skin, from pigmented moles, or otherwise, have the property of alveolar arrangement of spheroidal cells, whilst they metastasize by the lymphatics. It is found, however, that the metastases show less and less of the alveolar arrangement, and the cells gradually approach one of the types of sarcoma. Nor are metastases confined to the lymphatics, though initially so, and it may well be that lymphatic spread in these so-called melanotic carcinomata is determined by their superficial origin.

Ribbert (1897) states that all melanotic tumours have a common origin, be their starting-point the skin, mole, eye, or other pigmented area, namely, in a cell mesoblastic in origin, differentiated from the fibrous-tissue cell and existing as a producer of melanin pigment. Such cells he termed chromatophores.

The different cellular arrangements and characters which distinguish melanotic tumours he related to the degree of maturity possessed by the parent chromatophore. Thus the tumour arising from the immature chromatophore of the congenital pigmented mole was more likely to be spheroidal and alveolar in character than the melanoma having its origin in the mature chromatophore of the skin or uveal tract. A recent study of the histology of a series of melanomata of the skin by Hertzler and Gibson bears out this assertion. Ribbert further held that, though the chromatophore is mesoblastic in origin, it was pathologically inexact to define its tumours as sarcomatous, for like the endothelioma it was worthy of a special designation, and such he found in the word 'melanoblastoma'.

The most striking feature of the foregoing history is the long interval between the original incidence of the primary eye tumour and the subsequent metastasis. The assumption is natural that the scapular growth is the result of dissemination of the recurrence which has gradually manifested itself over the last twelve months, but that in no way detracts from the interest attached to his eighteen years' freedom from affliction. It is authoritatively stated that the expectation of life in melanomata of the eye is rarely more than three years (Bland Sutton). Cases are, however, reported in which dissemination has been as long delayed as eleven years. The interval described in the present case is apparently unique, whether applied to local recurrence or dissemination.

The dissemination of melanosarcomata, taking place as it does by the blood-vessels, is body wide, each and every tissue being traversed by the invader. It is exceptional under these circumstances, therefore, for a metastasis to be single and sufficiently dominant in its exhibition to warrant treatment directed towards its removal. Careful examination, however, failed to reveal any symptom or sign of further metastatic growth, though complete *x*-ray examination might have demonstrated osseous foci elsewhere.

The destruction of bone and its replacement by tumour forms a feature of note, providing a contrast between tumours of the scapula which are primary, and this which is metastatic.

Examination of the tumours of the scapula in the University Surgical Museum and in the Royal College of Surgeons (Ed.) Museum shows that these are all examples of primary tumours. Their origin is in each case superficial or periosteal, and growth takes place freely over the surface of the bone. The shape and form of the tumour is defined by the muscles which pass over it, whilst they may or may not be invaded according to the pathological nature of the neoplasm. Continuity with a similar tumour on the other side of the scapula is effective by extension round one or other scapular border. Invasion and gross destruction of bone is not a feature of the progress of the tumour. Secondary tumours of the scapula are rare, and whilst Syme in his original commentary on the operation for the removal of the scapula refers to two cases of metastatic growth in the scapula, they were tumours spreading to the scapula by direct continuity, and not embolic.

The invasion and destruction of bone manifest in the present specimen is explained by the medullary origin of the metastasis. Destruction has been too rapid to have allowed of the expansion of the scapula, as may be seen in central tumours of long bones; whilst, once free from the osseous confines, the tumour has grown unrestrained along the surface of the bone on both ventral and dorsal aspects. This central origin is of course in accordance with the embolic origin of the tumour, for the slowed stream of the comparatively widened osseous blood-spaces provides an opportunity for the neoplasmic cells to find a foothold.

Secondary tumours in bone are as a rule cancerous in origin. Sarcomatous metastases occur in bone with far less frequency. Melanotic tumours are not covered by this generalization and frequently reproduce themselves in osseous tissue. There is, however, a definite order of frequency in which the bones are affected; and the vertebræ, femur, ribs, sternum, humerus, and cranial bones are, in the above order, the most usual locations of secondary growths.

The exhaustive inquiries of Von Recklinghausen as to the liability of the different bones to metastasis does not lead him to refer to the scapula at all, so rarely is it the seat of such a growth.

The factors which are held to determine the incidence of secondary tumours in bone are those of sudden strain or stress with corresponding alteration in the blood-current in the medullary spaces, and in practice the bones most frequently suffering are those subject to the above conditions. The scapula, however, may be considered to live, as far as bones go, a placid, protected existence, and no special circumstances which would explain the unusual incidence, such as occupation or trauma, could be detected in this case.

I am indebted to Professor Alexis Thomson for permission to publish this case.

A CASE OF GUMMATOUS PANCREATITIS WITH PHYSICAL SIGNS RESEMBLING ACUTE CHOLECYSTITIS.

By PHILIP H. MITCHINER, London.

The patient, J. K., a married woman, age 48, was admitted to the Royal Northern Hospital with a twenty-four hours' history of acute abdominal pain and vomiting.

The previous history of the patient was that up to November, 1921, she had been quite well; since that time she had suffered from attacks of abdominal pain, which started in the epigastrium and then travelled to the right scapular region, with accompanying vomiting. These attacks were becoming more frequent and severe. No definite history of indigestion was forthcoming, but the patient had been jaundiced, following one or two of the attacks of pain. The patient has one child, age 9 years, and has had one miscarriage since; her husband is alive and in good health.

The present attack, which was by far the most severe yet experienced, commenced some twenty hours before admission with intense epigastric pain, which radiated to the scapular region, and was accompanied by severe vomiting. The bowels had not been opened for two days, nor had anything abnormal been observed in the stools.

On examination, a well-nourished but anæmic woman, with slight jaundice. Pulse 104, rapid and of poor volume. Temperature 97·6° (reported by doctor to have been 102·4° earlier in the day). Tongue dry and coated, breath foul. The woman was collapsed and evidently in great pain.

The abdomen was not moving on respiration, and the epigastrium retracted. There was marked muscular rigidity on the right side, especially in the hypochondrium. Palpation in this region elicited extreme tenderness, which was greater on deep palpation. The abdominal reflexes were absent on the right side. Peristalsis could be heard all over the abdomen. A mass could be detected in the right hypochondrium, coming down from under the costal margin. It was indefinite in outline, fixed, and tender to the touch. No movement was detected on respiration. Examination of the chest showed diminished air entry at the right base; it was otherwise negative.

In view of the situation of the pain, abdominal signs, and previous history, a diagnosis of acute cholecystitis with perforation was made, and laparotomy was performed by a subcostal incision on the right side.

The gall-bladder presented and was seen to be normal. There was a little free fluid in the peritoneal cavity. A stony-hard mass about the size of a fist was felt in the head of the pancreas, sharply limited below and to the right, but extending up behind the pyloric end of the stomach, and joining with a large fixed mass in the gastrohepatic omentum. This at first sight suggested carcinoma, but further investigation showed it was not fixed to the posterior abdominal parietes, duodenum, or stomach wall; there was, however, distinct constriction of the pyloric end of the stomach due to fibrosis in the mass in this situation.

The omental mass was incised, when about a drachm of blood-stained grumous material escaped, there having apparently been a recent hæmorrhage in this situation. A portion of the mass was removed for microscopy, and the peritoneum sutured. The abdomen was then closed and the wall sutured in layers.

A diagnosis of gummatous disease was made, and in consequence the blood taken for a Wassermann reaction. The patient ceased vomiting, and made an uninterrupted recovery. The Wassermann reaction was very strongly positive.

The microscopical report on the tissue removed, furnished by Dr. Shaw, Director of Clinical Pathology to Royal Northern Hospital, was as follows: "A mass of omentum and fibrofatty tissue, showing extensive chronic inflammation, and round-celled infiltration, probably gummatous."

The points of interest in this case in regard to diagnosis, are:—

1. The diagnosis of perforation of an acutely-inflamed gall-bladder, which was assuredly justified on the physical signs. The subnormal temperature and collapse were taken to indicate recent perforation, and so the absence of peritonitis—as shown by the fact that normal peristalsis was heard all over the abdomen—was regarded as due to its not having had time to develop.

2. The possibility, from a superficial examination of the hard craggy mass in the head of the pancreas, of making a diagnosis of carcinoma of that organ and thus of giving a hopeless prognosis. Only a more careful examination showed that the mass was extending in one direction only, i.e., upwards, and did not seem to infiltrate the surrounding tissues in all directions, and tended to negative this diagnosis, as did also the normal appearance of the gall-bladder and bile-ducts; carcinoma could not, however, be definitely put out of court on a naked-eye examination alone. Microscopy and the Wassermann reaction were needed in order to make the diagnosis clear.

3. The vomiting and pain. These were due apparently to temporary pyloric obstruction from pressure caused by the breaking down of gummatous material, and the consequent stretching of the peritoneum over the mass, with pressure on the pyloric end of the stomach.

A CASE OF CALCIFIED GLAND OF UNUSUAL SIZE GIVING RISE TO DYSPHAGIA.

By C. P. G. WAKELEY, London.

The patient, a man, age 54, was admitted to King's College Hospital in May 1922, complaining of a lump in his abdomen. This lump was first noticed about a year previously, and gave rise to no pain until three months before admission, when the patient first noticed that at times he had difficulty in swallowing solid food. Liquid foods were easily taken and gave rise to no trouble. It was the dysphagia and loss of weight which brought the patient to hospital.

On Examination.—The patient was somewhat emaciated and was suffering from anæmia. A report of his blood examination was as follows: Red corpuscles, 4,104,000

Fig. 244.—Radiogram taken twenty minutes after a barium meal.

per c.mm., or 82 per cent of normal; hæmoglobin, 65 per cent of normal; colour index, 0·8; leucocytes, 14,000 per c.mm. The urine was normal. Wassermann reaction was negative. On examination of the abdomen a hard solid tumour was felt to the left side of the epigastrium. It was about the size of an orange, and could be easily moved about the abdomen. It could not be felt on examination per rectum. A full-size œsophageal bougie was easily passed, demonstrating no obstruction in the œsophagus.

An opaque barium meal was given to the patient, and a radiogram taken twenty minutes afterwards (*Fig.* 244). The stomach was of normal size and shape, and a duodenal cap was just beginning to form. A large, somewhat circular opacity of about three inches diameter was seen lying over the promontory of the sacrum. Subsequent skiagrams

proved the intestinal tract to be normal from the radiographic standpoint. *Fig.* 245 is a radiogram taken twenty-four hours after the ingestion of the opaque meal: it shows the barium in the cæcum, ascending and transverse colon, and splenic flexure. The opaque rounded body can be easily seen.

Six days after the barium meal another skiagram was taken. with the patient in the upright position. The opaque body was then seen to be overhanging the brim of the pelvis.

The diagnosis seemed to rest between a calcified dermoid cyst and an enormous calcareous gland in the mesentery.

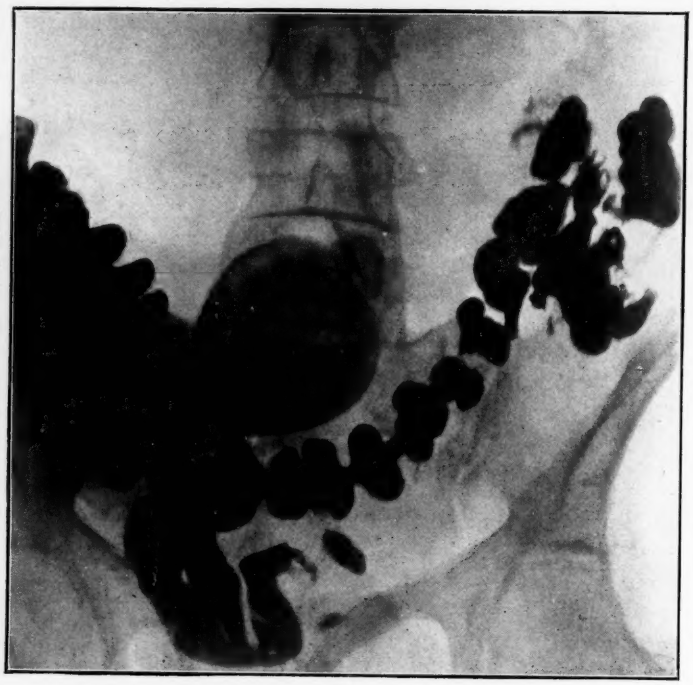

FIG. 245.—Radiogram taken twenty-four hours after a barium meal.

A laparotomy was performed by Mr. Burghard, in May, 1922. Under the anæsthetic the lump could easily be moved diagonally across the abdomen in the line of the mesentery. On opening the abdomen through a left rectus incision, a large calcareous mass in the mesentery was delivered; this was carefully dissected out of the mesentery by incising the upper leaf of the membrane; great care was taken, because the branches of the superior mesenteric artery and vein were stretched out over the mass, and a few had to be divided between ligatures. After removal of the tumour, the peritoneum was carefully sutured and the vitality of the gut was not endangered. The abdominal wound was closed in layers. The gland, which was almost calcified throughout, and is shown in reduced form in *Fig.* 246, measured three inches across, about the size of a large orange.

FIG. 246.—From a photograph of the gland. (× ½.)

The patient left hospital after two weeks; he could eat anything, and he has been seen since and has gained almost a stone in weight. This case is of interest because of the unusual size of the calcified gland, and its pressure effect on the stomach.

UNUSUAL COMPLICATIONS IN TWO CASES OF FEMORAL HERNIA.

By S. LAWRENCE LUDBROOK, New Zealand.

1. ACUTE APPENDICITIS IN THE SAC OF A FEMORAL HERNIA.

The incarceration of the vermiform appendix in the sac of a right femoral hernia is a well-recognized surgical possibility, and the appendix may of course become inflamed whilst in this abnormal position; indeed, it must be especially liable to do so by reason of the necessary interference with its blood-supply and stagnation of its contents. The following case illustrates the sequence of events, and serves to emphasize the great difficulty presented in diagnosis. For these reasons it is thought worthy of a brief record.

H. C., a man, age 36, was admitted to hospital April 19, 1922, complaining of a painful swelling in the right groin.

History of Illness.—The patient was an exceptionally healthy man until six months previously, when he noticed a small swelling in his right groin. Soon after it first appeared it quite suddenly began to increase rapidly in size, and became red and painful. He consulted a medical man, who diagnosed tuberculous abscess from broken-down lymph glands. The condition was treated by aspiration, when a quantity of sero-pus was removed. This relieved the pain, and the patient was able to resume work.

Three months later he had a sudden attack of very intense pain radiating from the umbilicus downwards and laterally into the right iliac fossa and the thigh. The acute pain lasted eighteen hours, and was followed by a soreness lasting several days. A few hours after the pain had ceased the swelling became enlarged and tender. After recovering from this attack he carried on his work for another six weeks, when he had another attack very similar in character, but not so intense. It was after this last attack had quietened down that he was admitted to hospital.

During the six months he had lost a good deal of weight, and had been troubled with loss of appetite and constipation.

Examination.—On admission, temperature was 99°, and pulse 72. The patient was thin, and not complaining of any pain. A hard nodular mass was found in Scarpa's triangle on the right side. The overlying skin was red, slightly œdematous, and seemed to be attached to the mass. No impulse could be felt on coughing, and no fluctuation elicited. The mass was quite irreducible.

Diagnosis.—A diagnosis of femoral hernia was made with a good deal of uncertainty, and an operation was performed on April 26.

Operation.—An oblique 'inguinal' incision, curving vertically downwards at its inner end, was made, and a flap thus turned outwards, some difficulty being experienced in separating the adherent skin from the thickened mass of inflamed glands, which formed the more superficial part of the mass. Some of the glands contained thick yellow pus. By dissecting round the upper part of the mass the greatly thickened hernial sac was discovered.

On opening into the sac it was found to contain the appendix, acutely inflamed, and firmly attached to the end of the sac. The opening into the abdomen was obliterated by adhesions to the neck. The inguinal wound was temporarily packed off, and the abdomen opened by a separate pararectal incision. The cæcum was brought into the wound, and the appendix removed at its junction with the cæcum, the stump being buried in the usual manner. A ligature was applied to the cut end of the appendix, the hernial sac was cut through at the neck, and the stump of the appendix everted through the sac. The lymph glands, thickened sac, and appendix were then removed *en masse*. The femoral canal was repaired, and the wound completely closed.

Healing took place by first intention, the patient being discharged on May 2 to a convalescent home.

The photographs (*Figs.* 247, 248) show both aspects of the specimen: the appendix lying in the enormously thickened sac, and adherent at its tip to the fundus of the sac. The outside of the sac fundus is covered by a mass of adherent lymph glands.

Figs. 247, 248.—Showing the appendix in the sac of the hernia, both aspects.
A, Appendix. S, Sac wall with glands adherent.

2. A CASE OF RIGHT FEMORAL HERNIA COMPLICATED BY A MECKEL'S DIVERTICULUM ADHERENT TO THE HERNIAL SAC.

THIS case is of interest as compared with the above one of appendicitis occurring in the sac of a right femoral hernia, and also as an example of one of the more unusual complications of abdominal hernia, more especially of the right side.

F. E., a man, age 52, was admitted to hospital on May 21, 1922, complaining of a painful swelling in the right groin.

HISTORY.—Eight years previously the patient developed a swelling in the right groin. This was reduced, and after wearing a truss for some years it disappeared completely and caused no further symptoms until a fortnight before admission, when it reappeared. Four days later the swelling became painful, and he found that he could not reduce it.

EXAMINATION.—This disclosed a soft swelling on the right side below Poupart's ligament, and below and external to the pubic spine. The swelling was quite soft, gurgled on manipulation, and a definite impulse was felt on coughing, but the bowel contents of the hernia could not be reduced.

OPERATION.—An oblique inguinal incision was made, extending vertically downwards at the inner end into the groin. A flap was turned outwards, and the hernial sac isolated from the subcutaneous tissues and incised. The incision opened bowel, which on further investigation proved to be the thin-walled apex of a Meckel's diverticulum adherent to the sac. The diverticulum was closed and, after careful dissection, separated from the sac and returned to the abdomen. The abdomen was then opened by a right pararectal incision, the diverticulum clamped and removed, and the bowel wall sewn over. The hernial sac was then dealt with in the usual manner.

Both these cases were operated upon by Mr. T. Twistington Higgins, and I am indebted to him for permission to publish them.

ULCERATION OF THE RECTUM, WITH PERFORATION INTO THE PELVIC CAVITY, AND PROLAPSE OF ILEUM PER ANUM.

By CYRIL H. CUFF, St. Lucia, B.W.I.

The patient, a West Indian man, age 30, was admitted to the Victoria Hospital, Castries, Feb. 3, 1922.

History.—In November, 1921, the patient came into hospital complaining of difficulty of micturition. He had a stricture which admitted a No. 8 bougie. He refused to stay for treatment, and left on the following day.

On Re-admission, Feb. 3, 1922.—The patient presented an extraordinary appearance. He was lying on his face vomiting copiously, and protruding from his anus were coils of distended small intestine, about four feet in length, and of a dark-blue colour (*Fig.* 249). The temperature was 97°, pulse 70 ; the patient cold and collapsed. He stated that sixteen

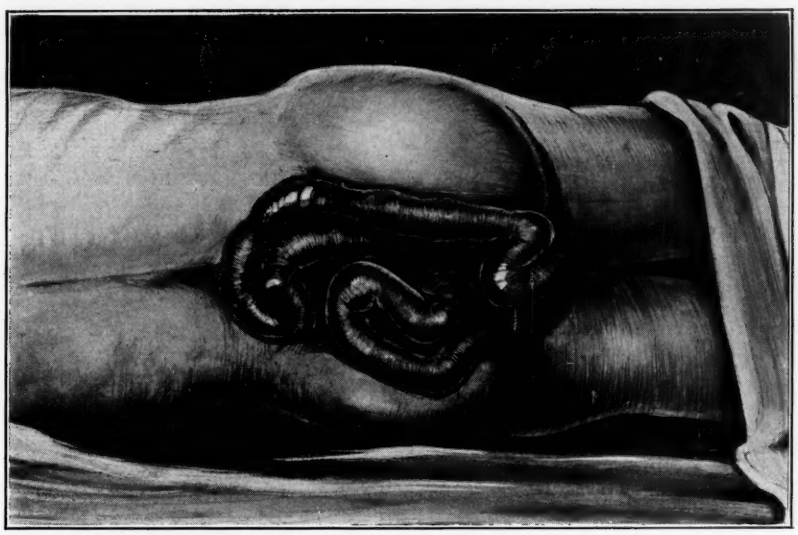

Fig. 249.—Showing the condition of the prolapsed portion of the ileum.
(*The illustrations are all reproduced from the original sketches.*)

hours previously, whilst straining to pass urine, " he felt something go inside," and experienced a peculiar sensation about the anus, and a " sinking feeling " in the abdomen. He then became aware of something moist and warm between his thighs, and on inspection found several inches of intestine prolapsed. He was far away in the bush at the time, and sent for assistance. Meanwhile the desire to micturate still being present and the strain continuing, more bowel descended and in due course began to distend. He then began to vomit and experience severe abdominal pain, especially in the region of the umbilicus. Help arriving, he was carried twelve miles in a hammock to hospital. Obviously there was some abnormal communication between the rectum and the peritoneal cavity, and the prolapsed gut was either constricted thereat, or twisted upon itself. It was decided to attempt a reduction, as offering the only chance of recovery ; and a preliminary intravenous saline was administered.

Operation.—Spinal analgesia (stovaine) being induced, and with the patient in the lithotomy position, the prolapsed bowel was thoroughly washed with warm saline and covered with hot towels. The abdomen was then opened in the middle line below the umbilicus,

and the intestines carefully packed off. It was now seen that a loop of ileum, about six feet from the ileocæcal valve, led down to the right pararectal fossa, where it disappeared through an opening in the peritoneum and side of the rectum, just above the lateral reflexion. Gentle pressure was now applied from below, while the bowel above was carefully manipulated. The constriction was found to be slight, but the prolapsed bowel was twisted about three-quarters of a circle upon itself. The volvulus (a secondary one) was corrected and the bowel returned without difficulty. The general appearance of the gut improved considerably, and it was decided to leave it in the abdomen. A long gauze drain was passed through the opening from the pelvis and out at the anus. The patient being extremely collapsed, the wound was closed with through-and-through sutures, and a further saline with pituitrin given.

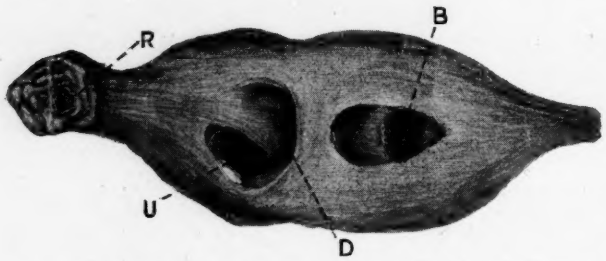

FIG. 250.—Superior view of the specimen: (R) Rectum; (B) Bladder; (U) Site of perforation; (D) Pouch of Douglas.

About two hours after his return to bed, the patient appeared much better, though the pulse was almost imperceptible. Continuous subcutaneous saline was kept up during the night. At 11 a.m. the following day, patient stated that he felt very weak. He was quite pulseless and obviously dying. At 11.30 he was dead.

POST-MORTEM EXAMINATION.—At the post-mortem, the whole of the rectum, bladder, and pelvic peritoneum were removed *en bloc* and the bowel slit open from behind. The mucous membrane showed several small ragged ulcers, varying from minute spots to the size of a shilling. The edges were irregular, and the floor rough and covered with mucus. There were numerous petechial hæmorrhages. The site of perforation was situated about $3\frac{1}{2}$ in. from the anus, on the right lateral wall. It measured about 1 in. by $\frac{3}{4}$ in., and was roughly circular. The edges were rough, somewhat undermined, and rather hard. The overlying peritoneum was fairly adherent and, where perforated, was white and fibrous, with jagged edges. (*Figs.* 250, 251.)

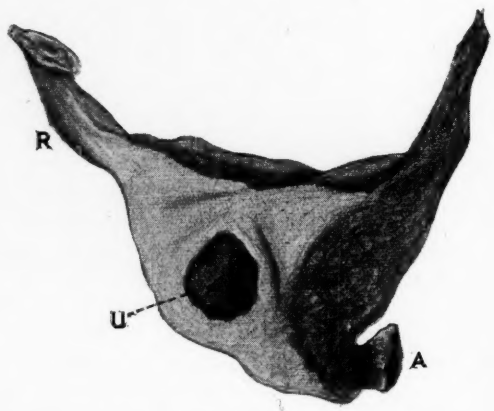

FIG. 251.—Lateral view of the specimen: (R) Rectum; (U) Site of perforation; (A) Anus.

The muscular coat of the bowel around this area was much thickened. The impression gained from an inspection of the specimen was that the floor of the ulcer had for some considerable time consisted solely of the thickened peritoneum, and that this had given way suddenly under the constant strain at micturition. There was no sign of ulceration elsewhere in the gastro-intestinal tract. The ulceration was probably of syphilitic origin, syphilis being not uncommon here. Microscopically there was merely a dense round-cell infiltration and fibrous overgrowth.

Bilharzia does not occur in St. Lucia.

I am indebted to Dr. H. G. Sutherland Richards, M.C., for the sketch of *Fig.* 249, and to Mr. Donald Devaux for *Figs.* 250 and 251.

TORSION OF THE GALL-BLADDER.

By C. H. S. FRANKAU, London.

Torsion of the gall-bladder is sufficiently rare to justify the recording of the following case.

The patient, a woman, age 62, twenty-four hours before admission into hospital complained of abdominal pain which commenced about an hour after her mid-day meal. The pain was mainly in the upper abdomen, and was colicky in nature; in the evening it became more intense, and she sought medical assistance. When seen by her doctor she had a normal temperature and pulse, and presented no abdominal signs apart from some tenderness in the upper abdomen. She was given a sedative and was relieved for a time; but during the night she commenced to vomit, and continued to do so incessantly. She was seen by her doctor the next morning, and immediately sent to hospital. There was no history of any previous abdominal trouble.

On Admission.—The patient looked ill. Temperature 97·6°, pulse 112, respirations 24. The tongue was dry and furred. The abdomen showed no distention; respiratory movements were almost completely absent. On palpation, there was general tenderness with rigidity: this was most marked in the right upper quadrant, where the rigidity was absolute. The lateral liver dullness was absent. No tumour could be felt, either before or after the induction of anæsthesia.

Fig. 252.—Gall-bladder, showing the constricting effect caused by the rotation.

In spite of the continued vomiting I considered the case to be one of perforation of a gastric or duodenal ulcer, and opened the abdomen through the right upper rectus shortly after her admission. On opening the peritoneum the liver, which was prolapsed, presented; on lifting the liver up, a small quantity of blood-stained fluid escaped, and the gall-bladder was seen to be black in colour, œdematous, and somewhat distended. Further investigation showed that the gall-bladder had rotated for one complete turn from right to left, the rotation being primarily on a short mesentery by which it was attached to the liver. The rotation on the mesentery had kinked the gall-bladder, so that its medial surface was markedly concave and a partial hour-glass constriction had been produced (*Fig.* 252). The mesentery was fan-shaped, being attached for a distance of 18 mm. to the gall-bladder and for about half as far again to the liver; the depth of the mesentery was approximately 30 mm., and its leaves at the hepatic attachment were in apposition. There were no stones in the gall-bladder, and the common duct was clear. The stomach was low in position, the gastrohepatic omentum being abnormally long; the right kidney did not appear to be unusually low or mobile.

The gall-bladder was separated from the liver by division of the mesentery, and removed after double ligature of the cystic duct. The abdomen was then closed in layers, a split tube drain being left down to the operation area. Recovery was uneventful.

Remarks.—The rarity of the condition is dependent on the infrequency with which the gall-bladder is completely surrounded by peritoneum and is suspended from the liver by a definite mesentery. A well-formed mesentery is present in about 5 per cent of gall-bladders, and only a small percentage of these hang free, since not infrequently a prolongation of the small omentum anchors the fundus to the duodenum or transverse colon.

Rotation in this case took place primarily on the mesentery, the cystic duct being only secondarily involved; this was made possible by the shape of the mesentery and

by its comparatively short length of attachment to the gall-bladder as compared with its hepatic attachment. In other respects the case conforms with those already published, for details of which, and for the sketch of the removed gall-bladder, I have to thank my friend Mr. J. A. Cairns Forsyth.

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REMOVAL OF A PIN FROM THE THIRD PART OF THE DUODENUM.

BY E. E. HUGHES, MANCHESTER.

THE patient, a girl, age 4 years, was admitted to the children's ward of the Ancoats Hospital on Sept. 1, 1921. The history, as given by the mother, was that the child had swallowed a pin. On *x*-ray examination a large pin was seen lying at the level of the 4th dorsal vertebra on the left side. The child was given porridge in the hope that the pin would be passed naturally. The following day it was seen to occupy the same position as on the previous day. On Sept. 3 a radiograph was taken, the child being in the supine position, and the pin was now seen to be at the level of the intervertebral disc between the 3rd and 4th lumbar vertebræ, and placed obliquely at an angle of 45° (*Fig.* 253). In the afternoon a simple enema was given, with a good result. On Sept. 4 the patient looked quite well and complained of no symptoms. Another radiograph was taken, and showed the pin lying in exactly the same position as on the previous day. Operation was decided upon for the following day.

FIG. 253.—Pin in third part of duodenum.

On Sept. 5 the abdominal cavity was opened through a right rectus incision. The stomach was first very carefully examined for the pin, with a negative result, and, similarly, the transverse colon. The whole length of the jejunum and ileum was next examined, without result. The incision was then slightly enlarged to allow of deeper access, and the duodenum was carefully examined. In the third part of the duodenum, about 2 inches from the duodenojejunal flexure, the pin could be felt, its point presenting forwards and upwards to the left. The point was expressed through the intestinal wall, and the pin was pulled through as far as its head would allow. A purse-string suture was then run round the pin, which was then extracted by a sharp tug. The orifice so made was immediately closed by the prepared suture, and reinforced by a few Lembert sutures. A long retrocæcal appendix in healthy condition was found, and removed. The abdominal wall

was sutured in layers. The patient bore the operation well, but suffered from a certain amount of shock. Rectal salines were given four-hourly for twenty-four hours, and fluids were administered by the mouth. On the following day the condition of the child was much improved, and thereafter she made an uninterrupted recovery. The patient left the hospital on Sept. 20 in excellent health, and with the wound soundly healed. Seen at intervals since discharge from the hospital, the child has continued to enjoy good health. The length of the pin—an ordinary domestic pin—was 34 mm.

I am indebted to Dr. J. M. Morison, radiographer to the Ancoats Hospital, for the radiographic print.

PANCREATIC FIBROSIS OBSTRUCTING BOTH THE COMMON BILE-DUCT AND THE DUODENUM. FIVE YEARS OF ACTIVE LIFE AFTER CHOLECYSTDUODENOSTOMY AND GASTROJEJUNOSTOMY BEFORE DEATH FROM CANCER.

By W. G. SPENCER, London.

In 1908 a cavalry officer, age 30, who had served for seven years in South Africa without illness, during the voyage home was seized with acute pain for the first time. After arrival he consulted Drs. Gee and Mitchell Bruce, and the diagnosis made was that he had had an attack of gall-stone colic. Dr. Ironside Bruce did not discover anything by *x*-ray examination. Obscure attacks of indigestion, without at any rate noticeable jaundice, followed, but his general health was not impaired, and he continued to play polo for his regiment.

In February, 1912, before the operation he presented two positive signs: slight resistance with tenderness on deep pressure under the right 9th rib cartilage, and Cammidge's urine reaction definitely positive. At the operation the head of the pancreas, without being enlarged, was found densely hard and nodular; it was also compressing both the common bile-duct and duodenum, causing some dilatation. In the search for calculi, the pancreas was cut into; it was densely hard, and grated under the knife like scirrhous cancer. On opening the duodenum, no change on the mucous aspect was found—only a compression of the lumen without any sign of a stone at the papilla or elsewhere in the bile-duct. The gall-bladder was unaltered and its contents were normal bile; it was anastomosed with the duodenum above the pancreas, and the abdominal wall closed except for a temporary drain. Recovery was complicated by gastric dilatation, relieved by washing out.

The dilatation became worse on getting up, so three weeks after the first operation, and after a consultation with Sir Rickman Godlee, gastrojejunostomy was done, when it was noted that all the body of the pancreas was unduly hard. The statement made, not to the patient, but to his brother-in-law, was that the disease was cancer. The patient made a rapid recovery, returned to his regiment, and resumed polo. Subsequently he married. On the outbreak of war he went out with his regiment as a major, and was in the retreat from Mons. He continued at the front and was twice wounded, when he had to return temporarily to England. He gained the D.S.O. and the Croix de Guerre; there is no report of any sickness until, in April, 1917, he was taken to hospital suffering from an acute abdominal attack. On exploration of the abdomen, generalized malignant disease was found, and he reached home a few days before his death a little more than five years after the two anastomoses. All that can be said is that the opinion given from observations made at the two operations was that the condition was already one of scirrhous cancer of the pancreas. It may be, however, that cancer supervened late upon a dense fibrosis.

TWO CASES OF RUPTURE OF THE RECTUM, COMMUNICATING WITH THE PERITONEAL CAVITY.

By W. G. SPENCER, London.

In the one case the end of the handle of a wheelbarrow, in the other the end of a chair leg, pushing the seat of the breeches in front of it, passed in through the anus and ruptured the anterior wall of the rectum.

Case 1.—It was only in the course of the coroner's inquest and of the inquiry held at the Hospital afterwards that the correct story of this accident was made out. When the offices of the Ministries of Health and of Education were in course of building, the man was standing on a wall which had been raised two feet from the ground, when he stepped backwards off the wall against a wheelbarrow. The wheelbarrow had been turned on its side so that the upper handle stood out an angle of some 45° from the horizontal. A fellow-workman assisted the patient about 100 yards to the Westminster Hospital, where he was seen by an assistant house surgeon, who noticed blood in the seat of the man's breeches and a small abrasion to one side of the anus. He applied an antiseptic dressing to this, and sent the man away. The house surgeon afterwards excused himself for not making any further examination or admitting the case, because the two men had given no clear account of what had happened, and he had mistaken for fright the man's general condition, which must have been due to shock. The man went home and—acute septic peritonitis setting in—he was admitted to the Bolingbroke Hospital, where an immediate operation was performed. A rupture of the rectum into the peritoneal cavity was found, but it was too late to save the patient's life.

Case 2.—A boy of 7, at Eastbourne, was playing at what he called 'submarines', in the course of which he had turned up the nursery chairs so that the hinder legs stood out at about 45° from the floor. Against one of these he staggered back and was able to give a sufficient explanation of what had happened to his mother, who found blood in the seat of his knickerbockers. She sent for Dr. Harper. There were no external signs of the accident; but there was a rent on the front wall of the rectum, and blood in the urine. Acute septic peritonitis became obvious within six hours of the accident, and we operated within twelve hours. The boy was then suffering from well-established septic pelvic peritonitis; the pulse-rate was 130 and small, the face pale and pinched, the abdomen already somewhat tympanitic. On making a median hypogastric incision, blood-stained septic fluid escaped, and the peritoneum was found inflamed, but no actual rent was detected. The urine contained blood, but the bladder proved watertight.

On dividing the sphincter ani backwards to the tip of the coccyx the rent in the rectum was fully exposed. It was situated on the anterior wall just above the internal sphincter; the margins were ragged and infiltrated by blood. Exploration with the finger and probe did not reveal any actual communication with the peritoneal cavity. The high position of the bladder and the formation of the pelvis in the little boy had caused the laceration to extend into the rectovesical fascia, and the actual penetration of the peritoneal cavity must have been a merely valvular puncture, although sufficient to start acute septic peritonitis forthwith.

A consideration of the above features appeared to oppose any attempt at suturing the rectum. As the boy lay on his back there was a conical wound, the base of which was exposed so that a dressing could be applied to it. The blood in the urine could be accounted for by a contusion of the mucous membrane. Therefore the abdominal wall was sutured except for a drainage tube, the inner end of which lay over the bladder, which was kept empty by a rubber catheter retained in it. Dressings were applied to the laceration on the anterior wall of the rectum until the anus closed. The peritonitis was arrested, and all healed without complication, so that no trace of the accident remained.

REVIEWS AND NOTICES OF BOOKS.

Treatment of Injuries of the Peripheral Spinal Nerves. By Sir HAROLD STILES, K.B.E., F.R.C.S., Regius Professor of Clinical Surgery, University of Edinburgh ; and M. F. FORRESTER-BROWN, M.S., M.D., formerly Surgeon, Edinburgh War Hospital. Roy. 8vo. Pp. 180+viii. Illustrated. 1922. London : Oxford Medical Publications. 15s. net.

IN the introduction to this book, based on a large experience in the treatment of war nerve injuries, the writers set themselves the task " to map out for the surgeon who has no special experience of the subject those paths which will lead to a successful result for himself and his patient, and to help him to avoid those pitfalls which have entrapped most workers at first, before they learned to look out for them ". This has been successfully done.

The anatomy of the nerves most commonly injured is well described. There is one small point with which the reviewer disagrees. In *Fig. 3a*, depicting the sensory loss after complete division of the musculospiral nerve, an area of loss of epicritic and protopathic sensibility is shown over the terminal phalanx of the thumb on its dorsal aspect. In *Fig. 6b* this same area is given as being anæsthetic to deep pressure and pain after division of the median nerve. It cannot be usual to find these areas ; they may perhaps be accounted for by implication of branches of other cutaneous nerves in severe war injuries.

The section on diagnosis gives everything necessary in short compass, nothing important being omitted. The chapters on operations are the fullest that have been published, and treat the subject in an exceptionally able way, both from the general aspect and also in the description of its application to individual nerves. The volume closes with a clear description of the indications for tendon transplantation in nerve injuries and the methods of performing the operation. This is one of the most valuable chapters in an excellent manual.

The illustrations of operations are good, and indicate all the points clearly. Many of the reproductions of photographs, however, are so poor that it is difficult to make out the points they are inserted to show.

The writers are to be congratulated on the production of a book that should be in the hands of all who have to deal with this type of injury.

A Text-book of Surgical Anatomy. By WILLIAM FRANCIS CAMPBELL, A.B., M.D., F.A.C.S., Surgeon-in-chief, Trinity Hospital, New York. Third edition, revised. Medium 8vo. Pp. 861, with 325 illustrations. 1921. Philadelphia and London : W. B. Saunders Co. 30s. net.

FROM the fact that this volume has already gone through two editions, and some fourteen years after its first appearance is still in demand, one can only deduce that it filled a gap in surgical literature, or has created a place for itself. Destructive criticism in a review of a book of this kind is exceedingly easy, yet one cannot but compare the comparatively meagre and not always accurate letterpress of the volume under review with that mine of information in pocket form which we have known throughout our medical career as Treves' " Surgical Applied Anatomy ". As a make-weight on the other side of the balance, one must admit that with regard to print, paper, illustrations, and general appearance, the volume under review is as much in advance of any British publication of the same kind as American books—particularly those emanating from the house of Saunders—usually are. It is the letterpress that we find so poor and disappointing. For instance, we are told that preliminary ligature of the lingual artery is a simple and effectual means of lessening hæmorrhage during excision of the tongue, since there is little or no anastomosis between the two halves of the tongue. Surely it is agreed that this proceeding is only of preventive value if carried out within a few days of the excision, for the very reason which is the negation of that given above. Two paragraphs later follows a list of tumours which it is said are fairly common in the tongue. The value of such a statement is doubtful, even if its accuracy, which is not in agreement with our experience, is admitted.

On p. 171 a diagram shows six cords entering into the brachial plexus ; even if there were more than five of classic memory, they could not have the relations here depicted. Similarly a diagram on p. 297, though a beautiful and absolutely true representation of the common supra-condylar fracture of the humerus, is wrongly labelled " Separation of the epiphysis at elbow ".

It is a pity that there should still be text-books of merit which continue to spread the old mistake that this injury is a separation of the epiphysis. In truth, of course, the fracture involves the humerus some ¾ in. above the epiphyseal line, and it is difficult to understand how it can be caused by a fall on the elbow, or by 'jamming' the elbow in a door. It is to be regretted also that on p. 308 fixation of the forearm in fracture of both bones should be recommended midway between pronation and supination, though if the author's results are 'entirely satisfactory', he has been more fortunate than ourselves, and is to be congratulated. The spine and spinal cord are dismissed in thirteen pages, and we find no diagram showing the areas innervated by various segments. The clinical pictures of spina bifida and fractures of the spine are meagre, and anatomical facts connected with the common reflexes are entirely omitted.

While the illustrations are beautifully executed, and the majority serve to assist the reader, some would seem to be scarcely worth including. Those which appear on the pages dealing with hernia do not appear to be accurately drawn, and for a long time we failed to recognize the testicle. On p. 549 we are told that " tuberculous affections localize in the head of the epididymis ", a diagnostic point which we hoped had been discarded as untrue.

The recent researches of Flint into the anatomical variations of the common bile-duct have shown that in an appreciable percentage it is not formed until some distance below the normal level. It is to be doubted, however, if any of the variations demonstrated by Flint show the arrangement depicted on p. 431, nor is it helpful to the surgeon to remark that " the supraduodenal portion of the common bile-duct is very short ". The figure accompanying this statement is inaccurate in the same direction as the one on p. 431, and as the supraduodenal portion of the common bile-duct is the seat of election when surgical intervention is necessary, it would be more helpful to state its average length than to be satisfied with a remark such as that quoted above.

The figure on p. 279 depicts a " Claw hand due to paralysis of the ulnar nerve ". Surely such a condition as is here shown cannot result from a lesion of the ulnar nerve only. Similarly, in connection with the musculospiral nerve, it is an omission of considerable clinical importance not to point out that lesions near the elbow lead to non-sensory symptoms, and in a book of this size one would expect some real information about the anatomy of Erb's paralysis. On the whole, we very much prefer an old friend which may be carried easily in the pocket.

Collected Papers of the Mayo Clinic, Rochester, Minnesota. Vol. XI. 1919. Edited by MRS. M. H. MELLISH. Large 8vo. Pp. 1331. Illustrated. 1920. Philadelphia and London. W. B. Saunders Co.

WE have thought in the past that the view-point of work of the Mayo Clinic was somewhat confined to certain areas of the surgical field, and further, that it was limited, out of all fair proportion, to the clinical aspect of disease. If such criticisms were fair and accurate in the past, they can certainly no longer be upheld, for the papers comprised in this volume range over all parts of the body, and include the fields usually reserved for the specialists. Those which deal with surgery in its clinical aspect—and happily they still occur in a lesser proportion—because they are likely to interest our readers, receive a notice here out of all proportion to their number in the volume; but this must not be assumed to assess their value as high as those of wider or purely scientific interest.

As regards the range of subjects, it can scarcely be extended, as it includes on the one hand an article by L. B. Wilson on *Graduate Medical Education in Great Britain and France*, and on the other, *A Note on Scalpel Sharpening*. Having said this, the writer must confess that this extension of the field which has to be covered very much increases his difficulties, for it is scarcely possible for a reviewer to combine the capacity to assess the value of a purely clinical paper with that which would judge the real value and permanence of papers which deal with purely pathological problems. While in no sense assuming the knowledge fully to appreciate its value or meaning, the writer must confess that the first paper or series of papers which attracted his attention were those by Kendall and Osterberg, either alone or in combination, on *The Chemical Identification of Thyroxin and its Physiological Action*. Kendall's paper on the last subject is extraordinarily instructive and suggestive, and it is to be hoped that the line of investigation herein outlined will be pushed further, not only in relation to the influence which the active principle of thyroid has upon the human organism, but also with the object of estimating the individual and collective influence of the secretions of the endocrine glands upon normal and abnormal man.

Irene Sandiford's paper on *The Basal Metabolic Rate in Exophthalmic Goitre* is of the same high level, and of course has the immense advantage assured by all scientific papers from this Institution, in that it is based upon a wealth of clinical material.

One of the most fascinating and disappointing questions which seem recently to have come into increasing prominence in the world of surgery is that of organ transplantation. Kawamura reviews the history of this subject in his paper, which will be helpful to anybody contemplating either experimental or clinical work upon this question, for he lays down fairly definitely certain general principles which it is by now generally agreed dominate this question. He may claim to have proved that the thyroid gland and spleen may be transplanted with intact blood-supply

autoplastically but not homoplastically in the dog. It is to be hoped that the work of Carrel and others in the last fifteen years may enable us to see the day when organ transplantation may be a practical problem in man, and in any case those who have an acquaintance with the extraordinarily high level of technique demanded in this kind of experimental surgery—for Carrel noted in 1907 that it required a higher degree of asepsis than ordinary surgical procedures—must ungrudgingly award the experimenter a word of praise for his wonderful work.

In recent years Judd's writings have tended to centre round the urinary tract. His papers on surgery of the kidney and removal of stones from the ureter are sound, replete with clinical insight, and from the volume of experience which they represent would be invaluable to anyone embarking upon this type of surgery. They contain perhaps the most beautiful drawings which we have seen even from the pencil of Miss Fry. This artist's skill in the illustrations of Dr. C. H. Mayo's paper on *The Surgical Treatment of Cancer of the Stomach* does much to enhance its value. We assume that the selection of depicting those steps in the operation which appear to be essential and instructive has been in the surgeon's hands, but even then one may be permitted to remark that this selection to us appears to be ideal, and moreover that the illustrations, while artistically perfect, sacrifice nothing of clearness or detail to artistic effect.

Of the several papers on the treatment of the diseases of the duodenum and stomach which we naturally expect to find in any volume of this series, none calls for special attention, yet all justify their inclusion, because they push a stage further some suggestive line of thought, or endorse a principle or practice by showing that a further period of trial has proved its worth.

We do not appear to have come across J. C. Masson's writings in previous volumes, and if it is an oversight on our part, the loss is ours, for his short papers on *Exposure in Gall-bladder Surgery* are a model of what the description of an operation should be. T. B. Reeve's paper on *The Arterial Supply of the Stomach and Duodenum* is already widely known. It must represent a colossal piece of work, and the microphotographs of injected specimens have obviously been beautifully made. If he has not established any definite rôle for the anatomical arrangement of the vessels in the causation of ulcers, his work is at least sufficiently conclusive and exhaustive to indicate to others searching for the truth of this question that it is not along these lines that they must seek for the chief factor.

W. J. Mayo's paper on *Results of Splenectomy in the Anæmias* represents the best which such an aggregation of clinical experience can produce; as from no other one institution in the world can records of 61 splenectomies for splenic anæmia and 27 for hæmolytic icterus be brought together. The full value of such an experience will only be appreciated, and that most gratefully, by those whose opportunities for such work are few indeed.

Collected Papers of the Mayo Clinic, Rochester, Minnesota. Vol. XII. 1920. Edited by Mrs. M. H. Mellish. Large 8vo. Pp. 1392. Illustrated. 1921. Philadelphia and London: W. B. Saunders Co.

The Mayo Clinic has become since the war a vast Institution in which all the specialities and associated sciences are represented in the different departments. *Pari passu* with this extension and subdivision of their work, the type of papers comprised in the volume under review tends more than its forerunners to specialism, either clinical or scientific.

Eusterman contributes a valuable study of 83 gastroduodenal ulcers verified at operation, and concludes that this lesion is largely due to technical error or mechanical defect in the operation. MacCarty adds another of his papers on the *Classification of Neoplasms*. We have tried, from this writer's conception, a working classification which could be understood by the ordinary student, but must confess that the introduction of so many new terms, and such a vast number of subdivisions, makes it difficult, and we cannot think that his scheme is likely to meet with general adoption.

Henderson contributes several articles dealing with non-union, for which the use of beef-bone screws is advocated. The practice is ingenious, but seems to be contrary to the general principles which govern the present practice of bone surgery. It is admitted that their resistance to stress and strain is limited; as heterogenous absorbable material, it is clear that sooner or later they disappear, but no experimental or clinical evidence is forthcoming to suggest that this absorption does not antedate the true union of and around the graft. After reading these papers, we are at a loss to appreciate what advantages they possess over wire or metal screws, and it would appear that the difficulty of ensuring their sterility is far greater.

Masson reviews the statistics of over 40,000 herniæ, which comprise more than 2000 in the Mayo Clinic during the years 1915–17. He appears to accept the idea that the hernial sac may be either developmental or acquired. It is interesting to have statistical evidence of the success of the Mayo operation for umbilical hernia, for this operation in the hands of those who originated it gives a recurrence of less than 4 per cent. It seems at first sight strange that the Mayo series of 2000 cases should include only just over 100 femoral herniæ, and even when we take into account the fact that the period dealt with is that during which men were being rendered fit for military service, the proportion seems smaller than we should have anticipated. It appears that operation

from the thigh is regarded as entirely satisfactory, though Masson weakens his opinion in its favour by advising that, after the method of Coley, the pectineus muscle and the wall of the crural canal should be brought together with a mattress stitch. We must confess some disappointment that the inguinal operation does not commend itself to the surgeons of the Clinic, as we hoped to glean from this article some clinical evidence as to its value. Giffin's papers on *Splenectomy* crystallize views founded on large experience as to indications for and the value of this operation, and bring the immediate results of 245 splenectomies up to date. A few years ago it seemed from reports from the Mayo Clinic that splenectomy, when the spleen had been reduced by preliminary use of radium, held out some hope for patients suffering from myelogenous leukæmia. Giffin's opinion now seems to be that it is of doubtful value. The most satisfactory conclusion to be gathered from these articles is from a second report, which includes over 50 cases, in which the operation is shown to be of considerable value in pernicious anæmia. It is argued that, as in splenic anæmia, the indication for and value of splenectomy in pernicious anæmia is undue hæmolysis: taking the bile pigments as an indication of hæmolytic activity, evidence is deduced that at least a temporary reduction of the hæmolytic factor occurs in a very large proportion of cases.

Les Occlusions Aiguës et Subaiguës de l'Intestin. By A. C. GUILLAUME. Pp. 304, with 21 illustrations. 1922. Paris: Masson et Cie. 12 fr. net.

THE author's object in this monograph has been to correlate the clinical and pathological features of acute and subacute intestinal occlusion with the results of experimental investigations, and to found thereon a rational therapeusis. As is usual in France, the term 'occlusion' is limited to the acute or subacute condition, the chronic form being designated 'obstruction'. It is rightly pointed out that intestinal occlusion is not a pathological entity, but merely a syndrome—a complication which may supervene in the course of very diverse affections. Three groups of 'ileus' are described: (1) Ileus by strangulation, where the bowel is occluded by approximation of its walls; (2) Ileus by obturation, where the bowel is blocked by a body independent of the wall and mobile within the lumen; and (3) Paralytic ileus. Of these the first and second are usually grouped together as 'organic' or 'mechanical' ileus, in contrast with the third, which is described as 'functional' or 'dynamic' ileus; that two or more of these factors may be, and in practice are, usually found associated is properly insisted upon. We do not, however, consider that sufficient emphasis is laid upon the distinction between the earlier and local manifestations and the later general disturbances consequent upon them, and we prefer to limit the term 'acute ileus' to the latter, the local condition being referred to as 'acute intestinal obstruction': thus 'acute ileus' is the general condition brought about when a local 'acute intestinal obstruction' has been in existence for a sufficient length of time, and the whole trend of modern teaching is to prevent its supervention in any given case by means of early diagnosis and surgical treatment.

The work is divided into six chapters, dealing respectively with: (1) The general pathological anatomy of occlusion; (2) The clinical features; (3) Prognosis; (4) Diagnosis; (5) Physiopathology; and (6) Treatment. The general pathological features are well and concisely described, and attention is drawn to the changes occurring at a distance from the site of occlusion, as for example, the frequency of gangrene of the cæcum in obstructions of the sigmoid colon. The clinical signs associated with the various causes of occlusion are fully detailed, and are illustrated by typical case-histories, with operative findings. Particularly worthy of mention are the descriptions of occlusion from gall-stones and from lesions of the mesenteric vessels—embolism, thrombosis, and arteriosclerosis. It is shown that arteriosclerosis of the mesenteric vessels is much less uncommon than is usually supposed, and may occur in a localized form without any evidence of such changes in the radial or other artery accessible to palpation; its importance in relation to embolism is duly stressed, and doubt is thrown upon the possibility of ileus from a single embolus in a mesenteric vessel unless it be the site of previous arteriosclerosis. Slight degrees of vascular ileus are met with comparable with the 'intermittent claudication of Charcot' in the lower limbs, and arising from arterial spasm superimposed upon arteriosclerotic changes. Resection of the entire gangrenous area is the method of choice at present in the treatment of vascular ileus, although the mortality is given as 79 per cent. The question is discussed of possible operation upon the vessels themselves—the removal of the embolus, sympathectomy of the nerves of the vessels.

The chapter on prognosis is one of the best, and is based upon an analysis of over 700 cases of occlusion and 200 cases of strangulated hernia, the most recently published series of cases being included. The very much better prognosis of occlusion from external than from internal cause (such as strangulated hernia) is shown by a careful analysis of statistics to be due almost entirely to the difference in time before the condition is recognized and surgically treated, and a very strong plea is made for early diagnosis and early surgical intervention.

In discussing diagnosis, the value of auscultation of the abdomen—so often overlooked—is noted, and the importance of not waiting for the onset of fæcal vomiting in any doubtful case is rightly insisted upon. Greater value than we are inclined to assign is given to radiography, after opaque meal or enema, as a diagnostic measure in acute and subacute ileus, the examination being

made in the recumbent position ; this, however, is to be avoided if perforation of any part of the alimentary canal is suspected. It is urged that it is " not more dangerous to move a patient to the radiological examination table than to the operation theatre " !

In the section on physiopathology great stress is laid on the capital part played by toxic absorption from the contents of the bowel proximal to the obstruction, and many post-operative deaths are attributed to 'massive intoxication'. The absorptive power of the bowel above the obstruction is much diminished, whereas that below remains unimpaired ; when, therefore, the obstruction is relieved and the contents of the distended bowel are allowed to escape into the bowel below, toxins are rapidly absorbed and 'massive intoxication' results. On this, in the section on treatment, is based a very strong plea for the evacuation of the distended bowel by a small trocar before searching for the cause of the obstruction, and it is also advanced as a strong argument against entero-enterostomy in the neighbourhood of the obstruction. Since 'paralytic' ileus often persists after removal of the cause of the obstruction, it is recommended to leave a temporary fæcal fistula just above the site of the obstruction—in the large intestine by tying in a Paul's tube, in the small intestine by burying a small catheter in the bowel wall after the method of Witzel in gastrostomy. Exploratory laparotomy is advised in all cases of 'functional' ileus, since in a series of thirty cases it was found not to increase the risks, while it gives the security that an organic lesion is not being overlooked.

While this book does not introduce any strikingly new features, yet we can confidently recommend it as a very up-to-date and lucid exposition of the whole question of intestinal occlusion.

Rickets: A Study of Economic Conditions and their Effects on the Health of the Nation. By J. Lawson Dick, M.D., F.R.C.S. 8vo. Pp. 488. Two parts combined in one volume. Illustrated. 1922. London : Wm. Heinemann Ltd. 25s. net.

There is no disease that has attracted the attention of the clinician and the laboratory worker during recent years more than rickets. The reason is not far to seek. It is a disease that strangles a nation's vitality at its source and, as Sir William Jenner once said, it is the greatest indirect cause of infant mortality in this country.

The monograph entitled ' Rickets ' written by Mr. Lawson Dick is a book of nearly 500 pages, and it would be difficult to find a single page that could be dispensed with. The time is ripe for such a book, and the author has successfully brought together information from near and far and presented the profession with a treatise that should prove of great value to the cause of preventive medicine and national hygiene. The subject has been approached with wide vision and from the broadest standpoint, and the author has spared himself no pains in collecting evidence about the disease from many diverse sources.

The first part of the monograph deals with the world distribution of the disease and with its signs and symptoms. It may be said at once, from a perusal of this part of the book, that one is inevitably forced to the conclusion that the disease is one confined mainly to those parts of the world where dense masses of population are congregated together in industrial centres where sunshine is lacking, overcrowding is rampant, and the winters are long and trying. One is not long in waking up to the fact that Mr. Lawson Dick is a whole-hearted supporter of the environment factor of causation, and while many will be unprepared at the present time to accept this theory so whole-heartedly as the author, yet there can be little doubt that the evidences so ably presented by him throughout the book will convert many waverers to his side. The etiology of the disease is dealt with more especially in the second half of the book, where the experimental evidence is examined, and a legitimate criticism would be that while the dietetic theory is fully examined and discussed, yet in the end this factor is too easily put aside as of quite secondary importance in the development of the disease. We agree with the author that the dietetic theory fails to account for a large amount of rickets, and that defective environment and bad hygienic conditions more readily fit the situation ; but we do feel that there is a risk of allowing the pendulum to swing too far in the opposite direction. There are cases of rickets that one is unable to explain by the environment factor of causation, and there are children showing no evidence of the disease whose environment is so bad that it would seem on this theory to have been impossible for them to escape. While the actual determining factor still remains unsolved it would seem wiser to believe that both factors may be at work—the dietetic one becoming active when the environment and hygienic conditions are of the necessary type.

In the description of the signs and symptoms of rickets much valuable information is forthcoming. In discussing the earliest signs we are not sure that the author does not spread his net too wide, and it is doubtful whether all will agree with him when, on page 102, he writes that " the changes begin as a rule almost immediately after birth or within the first few weeks of extra-uterine life". There has recently been in some quarters a tendency to look upon most of the abnormalities of young infants as being of syphilitic origin, and it would be a pity if the same tendency were to show itself when dealing with rickets. Especially would this be so if the environment theory of causation were finally accepted. Physical and constitutional abnormalities certainly due to defect of diet might then run the risk of being included under the heading of rickets, and the importance of the diet gradually lost sight of.

The chapter dealing with the teeth in rickets is most acceptable, and is a part of the subject to which the author has given prolonged attention. From what he writes in the latter part of the book, where he deals with etiology, it would appear that he does not consider the changes in the teeth brought about by the experimental feeding of puppies during the investigations carried out by Dr. and Mrs. Mellanby are identical with the hypoplastic changes of true rickets. We are not convinced that the results of these important experiments can be so easily put aside as having little bearing on true rickets of childhood.

In the second part of the book the history of the disease is dealt with in a most interesting way, and the chapter "Glisson and his Times" is one of the most readable in the monograph. The literature of the disease is very fully given and will be of considerable value to future investigators.

The sections of the work which are of more exclusively surgical interest are those dealing with the mechanics of the development of deformities and with their subsequent treatment. It is easy to understand how bow-leg or knock-knee may progress, once a bias in the given direction has been acquired. The determination of this bias is convincingly explained by showing that the infant who shuffles will become bow-legged, while the infant who crawls will become knock-kneed. In considering deflection at the knee after walking has begun, one may, however, be permitted to doubt whether habitual eversion of the feet will tend to bow-legs, while retaining the feet parallel will incline to knock-knee deformity. The association of knock-knee with flat-foot is a well-established fact, and one may more readily believe that the 'position of rest' with everted feet will increase the strain on the internal lateral ligaments of the knees and lead to decreased pressure on the inner condyle, with its resulting overgrowth and knock-knee. The author definitely maintains the view that the static deformities of adolescents are mainly rickety in origin, either through the disease beginning at about puberty through a recrudescence of early disease, or through weakness of muscles, ligaments, or bones as a legacy of rickets in earlier life.

In a general work on rickets such as this, it is perhaps well that the author should avoid giving a full text-book account of surgical treatment such as is the province of a work on orthopædics. This aspect of the disease is dismissed in a few pages in which surgical principles are enunciated in a sound manner, but without sufficient detail to make them of more than suggestive value.

In conclusion, we would go so far as to say that we look upon this book as a milestone in the history and literature of this disease. It certainly will take its place as an important contribution to the cause of preventive medicine.

Text-book of Surgery for Students and Practitioners. By JOHN A. C. MACEWEN, M.B., C.M., Senior Assistant to the Regius Professor of Surgery in the University of Glasgow. 8vo. Pp. 619 + xxvi, with 535 illustrations. 1922. Glasgow: Maclehose, Jackson & Co. 30s. net.

THE volume before us adds one more to the many text-books of general surgery for students and practitioners; it has been produced at the request of many of the author's pupils, and is founded on the notes used by him in teaching. Within its six hundred pages is contained a very concise statement of general surgical affections and principles, affections of the various tissues, and regional surgery. Fractures and dislocations are omitted, as the author has already dealt with these in a separate manual. The general impression left by a study of the text-book is that on the whole it is good, but that the author has been carried away by his desire to omit nothing and has thus been led to include many rare conditions of little practical importance to a student, and to give such short accounts of various methods of treatment that they are of little use to the practitioner. In this respect the author might wisely have "consulted his own judgement" rather than, as he states in his preface, have considered the requirements of examiners, "particularly those who have done little or no teaching." Surely this variety of examiner must be a very rare specimen and hardly worthy of consideration! It thus comes about that in many places the reader finds a strange want of proportion, as, for instance, when twice as many lines are devoted to dislocation of the penis as to carcinoma of that organ.

In view of the vastness of the subject and the limitations of space, short dogmatic statements are unavoidable, and, speaking generally, these statements in most instances reflect the accepted teaching. On the other hand, there are many statements in the book to which the majority of surgeons would probably take exception. Thus, in the treatment of senile gangrene, the author states that it is rarely wise to amputate when the gangrene is spreading, as gangrene is apt to recur in the stump; that when amputation *is* performed it should generally be done at the knee; and that the flaps should not be sutured, but extended gently by strapping. Most surgeons, it is believed, would advise amputation in the majority of cases when the gangrene is spreading beyond the toes, would remove the limb through the lower part of the thigh, and would aim at primary union of the wound by accurate suturing of the flaps. In connection with tuberculous disease of the spine the student would certainly conclude that the most common cause of pressure paraplegia is acute angulation, although "occasionally pus from erosion of the vertebræ may work backwards", etc. In dealing with syphilitic affections of joints, painless effusion, especially in

the knee and sometimes bilateral, is mentioned as a late secondary manifestation of the acquired disease. It would have been more accurate to describe this form under the inherited type and to refer to its almost constant association with interstitial keratitis. Again, speaking of a tendon sheath, is it quite certain that "a simple ganglion is a protrusion of synovial membrane through an aperture in its fibrous envelope"?

In some practical advice on the examination of the breast, especially in the presence of a tumour, the importance of the recumbent position is not mentioned, and indeed, as it is stated that in examining the axilla the arm should be hanging by the side, it may be assumed that the patient is seated. It would be interesting to know whether the author has really seen relief of threatened suffocation due to cancer en cuirasse by making long incisions through the skin of the chest wall. We would take serious exception to the inclusion of acute appendicitis with strangulated hernia as the two most common causes of acute intestinal obstruction. In the practical consideration of an acute abdominal case most of the common conditions belong to one or other of two great classes, one in which a mechanical obstruction is present, and the other in which some form of acute peritoneal infection has occurred. Strangulated hernia belongs to one class and acute appendicitis to the other. The above are a few only of the statements to which exception may be taken; but even if all were mentioned there would still remain a large majority with which we entirely agree.

Finally, a few words may be said of the illustrations, which number five hundred and thirty-five. The best substitute for an actual patient or specimen is a good illustration, and of those before us it will be agreed that the majority, although small, are really useful, and their collection must have been no small labour to the author. On one page is a very useful group of four figures illustrating conditions which may resemble a strangulated hernia. We cannot, however, avoid the conclusion that many of the figures are useless. Acute inflammatory conditions rarely lend themselves to satisfactory illustration, and it may be doubted whether such figures as those of acute pyogenic ischiorectal abscess and large carbuncle of the neck are of any value. The same applies to some of the reproductions of radiograms and microscopic sections, and in many instances it requires a keen sense of imagination to discover the points which the illustration is intended to show.

The conclusion is that in a later edition of this text-book improvement might best be effected by a judicious removal of matter which is practically unimportant and a more ample consideration of what remains.

Artificial Limbs and Amputation Stumps: A Practical Handbook. By E. MUIRHEAD LITTLE, F.R.C.S. etc. Demy 8vo. Pp. 319 + viii, with 267 illustrations. 1922. London: H. K. Lewis & Co. Ltd. 18s. net.

MR. MUIRHEAD LITTLE has had a unique experience in dealing with the fitting of various types of prostheses during the last seven years, and the book is the outcome of his labours. He modestly states that he desires to record the conclusions that he amongst others has reached in the treatment of amputation stumps, and in the prescription and supervision of prostheses of some 25,000 cases. He does not pretend to offer a complete encyclopædic work, such as has been recently produced in Germany, but has restricted himself largely to British practice as laid down by the Ministry of Pensions, and he has also endeavoured to obviate the danger of the book becoming merely a compilation of limb-makers' catalogues. In both considerations he is to be congratulated, as the reader will wish to acquaint himself only with the most successful models and procedures, and surgeons will desire to fashion their work to the best advantage from the limb-makers' standpoint.

The historical chapter is a delight, and the illustrations and description of artificial arms of the time of Ambroise Paré bear striking resemblance to certain present-day types.

When dealing with amputation stumps one wishes that the author had laid down a few general principles for the avoidance of joint contractures, instead of merely mentioning the existence of such preventable deformities. He omits to mention that it has sometimes been necessary to divide the posterior ligament of the knee-joint in contracture following below-knee amputations where conservative methods of stretching have failed.

Mr. Little is a great advocate of end-bearing stumps in the leg and thigh; but however excellent in theory weight-bearing 'pad and sling' may be, the experiences of other surgeons do not quite coincide with the statistics given on page 50.

The chapter on cinematization makes sad reading, as the purely prosthetic difficulties have not been overcome. Despite the fact that work is still in progress in the experimental department of the Pensions Ministry, it is probable that the procedure will sink into oblivion.

A large amount of space and many illustrations are devoted to arm prostheses, the modern trend being towards working arms, heavy or light, with simple attachments, or to light dress arms of 'certalmid', which can be worn at the end of the day's work, or entirely for sedentary occupations.

As regards artificial hands, the author says truly that "they serve to some extent to mask the mutilation, and are occasionally useful. It is a matter of regret that more than this cannot

be said conscientiously of this part of the prosthesis, despite the ingenuity and industry of engineers and limb-makers during five centuries and especially during the last five years."

An interesting section on the relationship of normal gait and gait with an artificial leg contains the observations of du Bois-Reymond, and the later experiments of the Munitions Inventions Department, which were conducted with the aid of a slow-moving cinematograph.

Mr. Little has always been an advocate of a light limb, and the trend of modern design has had this aim in view. Prosthetic designs improve so rapidly that the book is already in danger of being out of date in this respect. A modification of the light duralumin Desoutter Limb with a wooden bucket is now being supplied in large numbers to pensioners. Other makers are bringing out similar types, so that the appendix devoted to specifications of the Standard Government Limb will before long require revision.

Mr. Little pays a graceful tribute to the progressive spirit displayed by the Pensions Ministry in its prosthetic policy. His innate modesty forbids him to state that he himself helped to mould it.

The book will rank as a standard work on a subject which requires for authorship a deep mechanical knowledge.

Surgical Pathology [Students' Synopsis Series]. By Eric Pearce Gould, M.D., F.R.C.S. Crown 8vo. Pp. 169+vi. 1922. London: J. and A. Churchill. 6s. net.

This is a little book of 165 pages which can be bought for six shillings. It belongs to the Students' Synopsis Series and conforms to type.

The fact that such books continue to be printed and are bought by successive generations of students proves that there is a demand for them, and they seem to fill a gap which exists either in the teaching given or in the minds of the students. Of its kind the book is quite good, and one can only hope that it is the prelude to some more enduring work from its author.